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Knowledge

SCIENCE • HISTORY • NATURE • FOR THE CURIOUS MIND

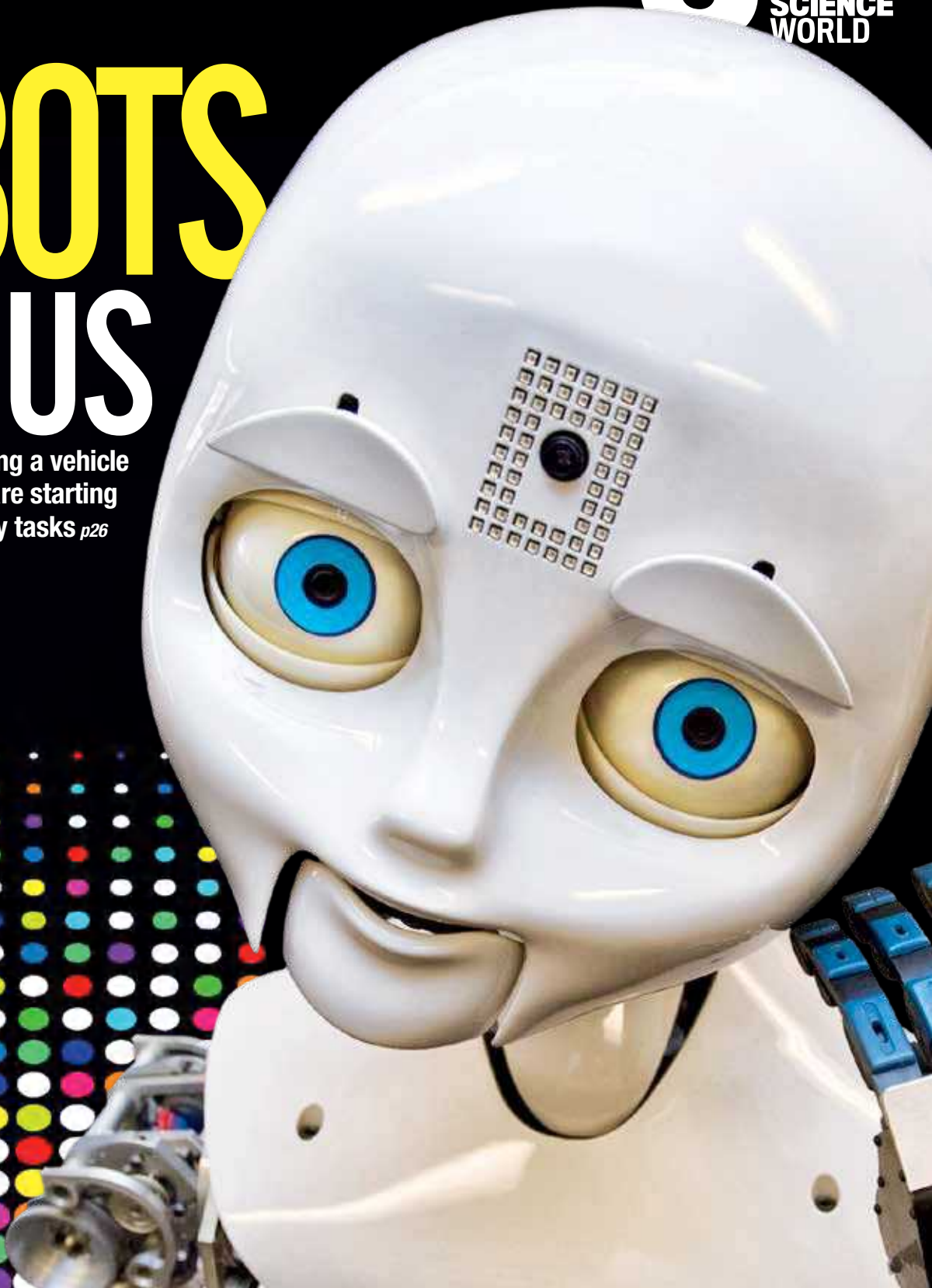
INCORPORATING

BBC

SCIENCE
WORLD

ROBOTS LIKE US

Opening a door or driving a vehicle
near you soon, robots are starting
to perform the everyday tasks *p26*



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R.N.J. MAHENG/2010/35422

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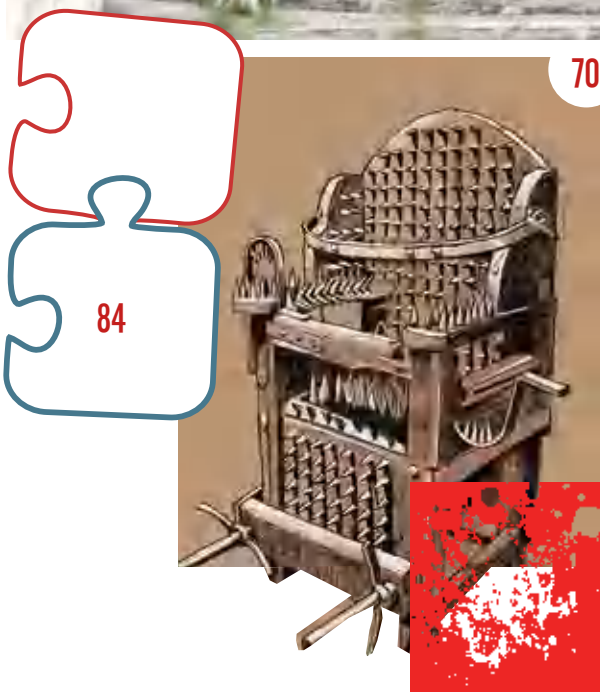
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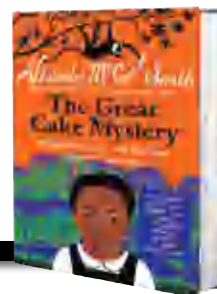
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FROM THE EDITOR



Science is so much fun, isn't it? As are our histories, and the natural world around us. There is so much to know; so many discoveries and innovations are being made everyday. Everyday, we live our lives a bit differently. And isn't it a joy to put together the puzzle pieces to figure out how and why?

This edition of Knowledge casts light on some such important pieces, pieces from pasts and futures. Take our cover story in **Robots Like**

Us (pg 26). It will give you a glimpse into a not too distant world where robots will be a normal part of our households. Perhaps something like in the movies *AI* and *Bicentennial Man*? Read about the innovators and the scientists who are tinkering away to make machines more like humans. Or read about **Babur** (pg 72), the first of the Moghuls, who changed the course of India like no one else did. Find out about the big questions that astronomers and physicists grapple with about our Universe. From questioning the Big Bang to chasing the mysterious Dark Energy. And for those who just thought sci-fi thrillers were just movies, think again – and read **The Trouble With Time Travel** (pg 62), where John Gribbin explores mind boggling concepts from the film *Back to the Future* that have scientists hooked.

This past month marked 70 years since the Hiroshima bombing. On August 6, 1945, the Atom Bomb was dropped on an unsuspecting city by the United States and the destruction that followed has been unparalleled in history. Read about what happened that day, and how humankind overcame its darkest hour in **Hiroshima: Rising From the Ashes** (pg 44).



edit.bbcknowledge@wmm.co.in
www.knowledgemagazine.in

EXPERTS THIS ISSUE



Duncan Graham-Rowe is a science writer based in the UK who has contributed to publications like *New Scientist*, *Technology Review* and *The Guardian*. In this issue, he explores the world of humanoid robots and their role in our future. **See page 26**



Mun Keat Looi is a science writer and the co-author of *Big Questions in Science: The Quest To Solve The Great Unknowns*. In this issue, he chronicles the resurgence of Hiroshima decades after its devastation at the hands of an atomic bomb. **See page 44**



Adam Hart is a professor of science communication and also delivers lectures and animal behaviour. He is a Fellow of the Royal Entomological Society. In this issue, he talks about the societal behaviour of wasps. **See page 68**



Diana Preston is one half of the historical writers collective operating under the pen name Alex Rutherford, and has co-authored the five-part historical series *Empire of the Moghul*. In this issue, she traces the journey of Babur, the founder of the Mughal Empire. **See page 72**



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Has something you've read in *BBC Knowledge Magazine* intrigued or excited you? Write in and share it with us. We'd love to hear from you and we'll publish a selection of your comments in the forthcoming issues.

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We welcome your letters, while reserving the right to edit them for length and clarity. By sending us your letter you permit us to publish it in the magazine. We regret that we cannot always reply personally to letters.



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HERE'S HOW TO GET IN TOUCH

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SALES

Director Brand Solutions

Jyoti Verma

jyoti.verma@wwm.co.in

WEST

Vice President

Gautam Chopra

gautam.chopra@wwm.co.in

MUMBAI

General Manager

Neelam Menon
Jiten Shivlani

neelam.menon@wwm.co.in
jiten.shivlani@wwm.co.in

AHMEDABAD

Jahnavi Bhojani

jahnavi.bhojani@wwm.co.in

NORTH

Vice President

Anjali Rathor

anjali.rathor@wwm.co.in

SOUTH

Assistant Vice President

Vikram Singh
Karthik Vijay

vikram.singh@wwm.co.in
karthik.vijay1@wwm.co.in

EAST

Assistant Vice President

Alka Kakar
Bijoy Choudhary

alka.kakar@wwm.co.in
bijoy.choudhary@wwm.co.in



Editorial, advertising and subscription enquiries

BBC Knowledge Magazine, Worldwide Media, The Times of India Building, 4th floor, Dr. D. N. Road, Mumbai 400001



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QA

EXPERT PANEL

Susan Blackmore (SB)

A visiting professor at the University of Plymouth, UK, Susan is an expert on psychology and evolution.

Alastair Gunn

Alastair is a radio astronomer at Jodrell Bank Centre for Astrophysics at the University of Manchester, UK.

Robert Matthews

Robert is a writer and researcher. He is a Visiting Reader in Science at Aston University, UK.

Gareth Mitchell

As well as lecturing at Imperial College London, Gareth is a presenter of *Click* on the BBC World Service.

Luis Villazon

Luis has a BSc in computing and an MSc in zoology from Oxford. His works include *How Cows Reach The Ground*.

ASK THE EXPERTS?

Email our panel at bbcknowledge@wmm.co.in
We're sorry, but we cannot reply to questions individually.

VITAL STATS

615%

Is the amount by which UK hospital admissions for anaphylaxis soared between 1992 and 2012

Can other animals plan ahead? p8 • Why does a banana skin get thinner as it ripens? p9 • Why does tape 'screech' when you peel it off? p10 • Can you prevent your phone being hacked? p12 • How does sunscreen protect you from sunburn? p13



Will spacesuits ever become less bulky?

They'll have to. Today's spacesuits are barely flexible enough to allow astronauts to float around in zero gravity. Space Shuttle pilots routinely had to remove their gloves during takeoff, just so they could operate the controls. On the Moon, astronauts hopped like kangaroos because they had so little range of motion in their legs.

Mars has double the Moon's gravity, so a suit that provides protection and can be comfortably worn for extended periods will be essential for future missions. Current experimental designs use body-hugging elastic materials to counter the pressure difference, while self-healing polymers automatically plug small tears. LV

MIT's BioSuit spacesuit concept being tested in a vertical wind tunnel



Do some facial expressions cause more wrinkles than others?

When you smile or frown, the creases in your skin begin as just temporary features. But as you get older, these same creases eventually become permanent wrinkles. Frowning mainly creases your brow, whereas a good smile will crease your eyes and mouth but not your forehead so much. The only expression that creases the entire face is the kind of horrified wince you make when you watch someone take a bad fall off a skateboard (try it!). This suggests that watching a lot of YouTube videos might just give you wrinkles! LV

Those eyebrows could do with a serious trim, too

How did humans tame wolves?

We still can't be certain of the time of dog domestication, but DNA evidence suggests that modern wolves and dogs are both descended from a wolf-like ancestor that lived in Europe at the same time as hunter-gatherer tribes, at least 11,000 years ago.

The two main hypotheses are that either wolves domesticated themselves, or they were domesticated by humans. In the first scenario, some wolves hung around human camps to scavenge on bones and leftovers, much like

urban foxes today. The hunters would likely only have tolerated the friendlier individuals, driving away or killing the more dangerous animals. This caused the ancestral wolf to split into a tamer subspecies that associated with humans, and a fiercer subspecies that stayed wild. The second scenario involves humans raising orphaned wolf cubs and breeding them. Studies have shown that modern wolf pups can be successfully domesticated from an early enough age. LV

"But I wanted a pony, Dad!"



Can other animals plan ahead?

You could argue that when a squirrel buries nuts, it is planning for the winter. But does the squirrel know it is doing this, or is it hard-wired behaviour? These things are hard to test, but experiments with scrub jays have shown that they will stash food in places where they expect to be hungry the next day. Meanwhile, a chimp called Santino living in a Swedish zoo has learned to hide piles of stones in advance so that he can pelt human onlookers to encourage them to move on. LV



Why does a squirrel hide its nuts?

This is what happens when you eat too much spicy curry before bed

How is lucid dreaming possible?

A lucid dream is when you know, at the time, that you're dreaming. The sensation is like 'waking up' in your sleep. You seem more alert, logical and self-aware and can even take control of the dream. Some lucid dreamers choose to fly and a rare few use the opportunity to meditate. I don't know why lucid dreaming should seem impossible, but it is becoming clearer how it works. Experiments, though difficult, can be done with expert lucid dreamers who signal to an

experimenter using eye movements. Their lucid dreams most often occur towards morning, at the end of a period of REM sleep when the brain is more active. Brain scans show the most active areas include parts of the prefrontal cortex and the temporoparietal junction where internal and sensory information come together to form our body schema and self image. This is probably why I feel more awake and 'myself' when I realise I'm dreaming. SB



Why does the Moon appear larger than normal on the horizon?

It has been known since ancient times (at least as far back as Aristotle in the 4th Century BC) that the Moon can appear to be larger than normal when close to the horizon. At the same time, however, it can be shown that the Moon is in fact no different in size than when it is at the zenith. This dichotomy is known as the 'Moon illusion'. Ptolemy and others have tried to attribute the phenomenon to the

refraction due to the atmosphere, but this is in fact erroneous. Although there is no definitive explanation, it is generally accepted that it is merely an effect of perception. When the Moon is close to the horizon, other objects such as buildings and trees are included in the eye's field of view. Most authorities suggest that this makes the Moon appear larger than when it's surrounded by an expanse of empty sky. AG



Party time for werewolves

What is the world's strongest truck?

The strongest truck is the BelAZ-75710. It holds the world record for being the largest two-axle dumper truck. It is almost the height of a house, with tyres measuring nearly four metres in

diameter. It can shift over 450 tonnes at a time, equivalent to 1,800 motorbikes. It has two 16-cylinder diesel engines dishing out as much power as 20 sports cars via four electric motors. GM

Just about the right size to shift the junk off our editor's desk...



What causes a halo around the Sun?

The appearance of a huge, perfectly circular halo round the Sun in Mexico earlier this year sparked rumours of the impending end of the world. In reality, it was the product of sunlight being refracted through hexagonal ice crystals high in the atmosphere. Water droplets can do the same, producing a smaller, more colourful halo. RM



Relax - a halo around the Sun is not a sign of the world ending

Why does a banana skin get thinner as it ripens?

Bananas are a cultivated form of plantain. In the wild, birds and bats are the main seed dispersers of plantains. While the fruit is developing, it is protected by a thick skin that keeps insects out. As the seeds become ripe, the fruit starts to absorb water from the inside of the skin, which causes the cells of the skin to collapse and lose rigidity. This makes it easier for animals to tear them open and carry off the little seeds along with a mouthful of banana. LV

Too squidgy for us, but yummy for a bat!



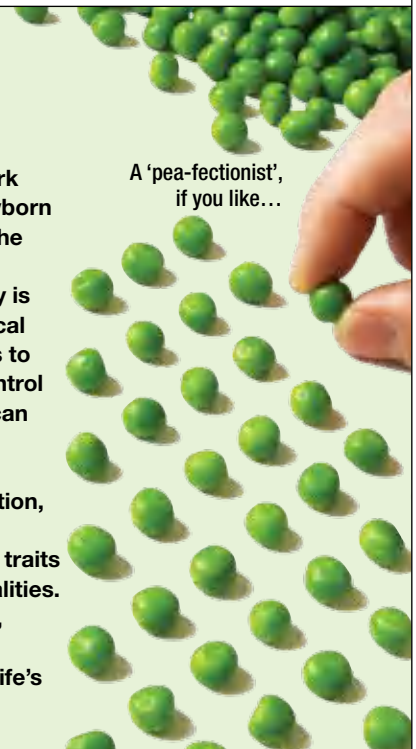
Why are some people perfectionists?

Because of the way genes and experience work together. Genetic effects are seen even in newborn babies, whose different temperaments show the beginnings of their personality.

Recent twin studies suggest that personality is more heritable than previously thought. Identical twins are twice as likely as non-identical twins to share qualities such as determination, self-control and a sense of purpose. While perfectionism can be positive, leading to high achievement, satisfaction and self-esteem, it can also be negative with harsh self-criticism, procrastination, disappointment and depression.

Both are related to the 'Big Five' personality traits that sum up our relatively stable adult personalities. These traits are openness, conscientiousness, extraversion, agreeableness and neuroticism. Yet all these traits are subject to the effect of life's encouraging or dispiriting experiences. SB

A 'pea-factionist', if you like...



TOP TEN COUNTRIES WITH MOST FACEBOOK USERS



1. UNITED STATES

Number of users: 152 million
Population: 319 million



2. INDIA

Number of users: 109 million
Population: 1.3 billion



3. BRAZIL

Number of users: 71 million
Population: 200 million



4. INDONESIA

Number of users: 60 million
Population: 250 million



5. MEXICO

Number of users: 44 million
Population: 122 million



6. PHILIPPINES

Number of users: 34 million
Population: 98 million



7. TURKEY

Number of users: 32 million
Population: 75 million



8. UNITED KINGDOM

Number of users: 30 million
Population: 64 million



9. JAPAN

Number of users: 27 million
Population: 127 million



10. FRANCE

Number of users: 23 million
Population: 66 million

VITAL STATS

£651m

Is contributed to the UK economy by bees, according to the University of Reading. This is because many crops rely on them for pollination

What's the longest railway tunnel in the world?

Line 3 of the Guangzhou Metro in China has a main branch line that is 60.4km (37.5 miles) long.

If you discount urban metro lines, the title goes to the Seikan Tunnel in Japan, which connects the islands of Hokkaido and Honshu. This is 53.85km (33.5 miles) long and is also the deepest rail tunnel in the world, running 100m below the seabed. This record will be beaten next year when the 57.1km (35.5-mile) Gotthard Base Tunnel through the Swiss Alps opens. But both of these tunnels will be eclipsed by the 123km (76.4-mile) Bohai Strait tunnel, which is planned to connect Dalian and Yantai in China by 2023. LV

Guangzhou Metro under construction

Why does tape 'screech' when you peel it off?

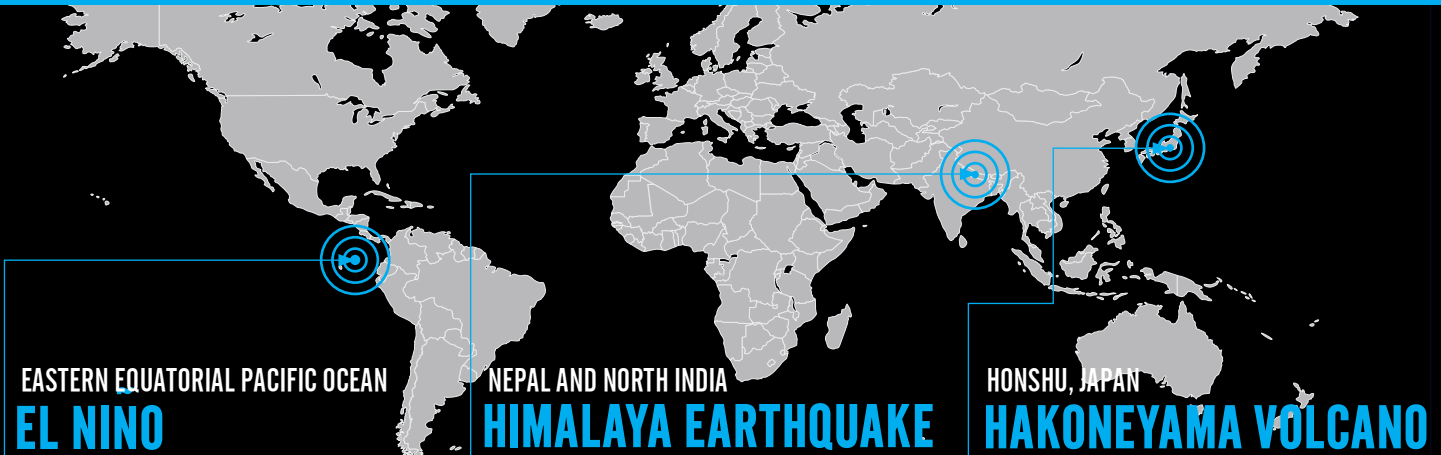
One easy way to infuriate your colleagues

Scientists have been investigating the source of this appalling noise since the 1990s, and have been amazed by the complexity of the phenomenon. Put simply, it's caused when the tape is peeled off at a speed and angle that causes the glue to intermittently stick then slip, creating jagged, unpleasant sound waves. RM



Where could the next natural disaster strike?

Around the world, catastrophic events are waiting to happen.
Bill McGuire reveals where nature is set to wreak havoc next



EASTERN EQUATORIAL PACIFIC OCEAN **EL NIÑO**



In June 2015, Honduras was already showing signs of drought from the El Niño phenomenon

El Niño is elusive, often threatening an appearance – as reported in this column in spring 2014 – that doesn't materialise. This time, however, it looks as if a whopping El Niño – the name given to the periodic accumulation of unusually warm water in the eastern equatorial Pacific – is definitely on its way. El Niño stirs up the world's weather and spawns a maelstrom of drought, floods and storms. Australian scientists are forecasting that the 2015 El Niño could be as intense the one that occurred between 1982 and 1983, which was blamed for at least 2,000 deaths worldwide. While Australia bakes, Europe and California can expect torrential rains and floods. Perhaps the only saving grace is that the arrival of El Niño invariably acts to put a lid on Atlantic hurricane activity.

NEPAL AND NORTH INDIA **HIMALAYA EARTHQUAKE**



Himalayan fault lines lie adjacent to heavily populated regions of northern India

Hard though it is to imagine, the magnitude 7.8 earthquake that devastated Nepal in April is pretty small in comparison to the huge quakes that are waiting in the wings. All along the Himalayan Front Fault, which marks the collision zone between the Eurasian tectonic plate to the north and the Indian Plate in the south, enough strain has already accumulated to trigger half a dozen quakes of magnitude 8 or more. One of these is due in the Himalayas, along a segment of the fault between Kathmandu and the Indian city of Dehradun. The region lies adjacent to the intensively farmed Ganges Plain and the teeming cities of north India, including New Delhi. Therefore, the earthquake – when it comes – is forecast to be cataclysmic. Some seismologists have even speculated that it could be the first one to take a million lives.

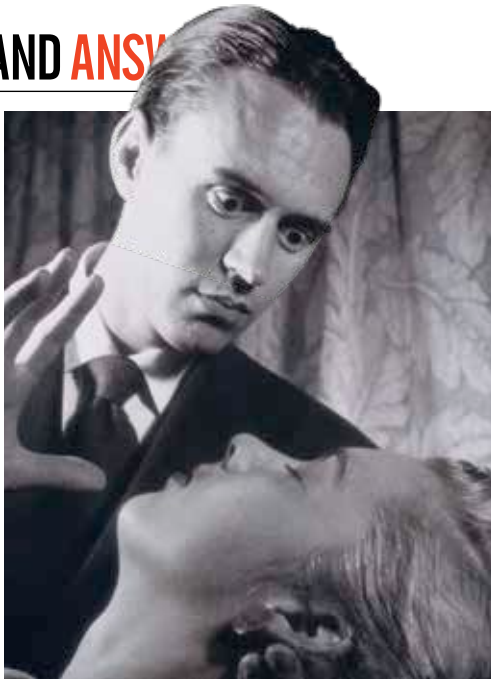
HONSHU, JAPAN **HAKONEYAMA VOLCANO**



Volcanic vapour spews from hot springs in Japan's Lake Ashi region

The water of Lake Ashi fills two giant calderas, with the largest one exceeding 10km in diameter. They were excavated by eruptions of the Hakoneyama volcano that took place around 50,000 and 180,000 years ago. Now, ominous signs suggest that magma may be on its way to the surface once again. Scientists have raised the threat level to 2 (on a scale of 5), in response to increased seismic activity beneath the volcano and vigorous steaming from hot springs. How big a future eruption will be is anyone's guess. It is even possible that the volcano will return to its slumber. Nonetheless, residents of this popular tourist resort remain on edge.

Bill McGuire is Emeritus Professor of Geophysical and Climate Hazards at University College London and wrote *Waking The Giant*.



Got creepy eyes? Become a hypnotist!

Is there any scientific explanation for hypnosis?

Not really – at least, not one that scientists can agree on. Hypnosis has been performed since at least the 18th Century when ‘Mesmerism’ was said to involve a ‘magnetic fluid’ or special force called ‘animal magnetism’.

This supposedly ‘scientific’ theory was abandoned when no evidence was forthcoming. In modern psychology, two main theories have long competed to explain the extraordinary effects hypnosis can have. State theorists claim that hypnotic suggestions induce an altered state of consciousness or hypnotic trance in which highly suggestible people are willing to obey the hypnotist and behave in uncharacteristic ways, such as remembering forgotten events, forgetting what they have just done and obeying post-hypnotic suggestions to perform some embarrassing action when given a cue. Non-state theorists claim that all these effects are better explained by role-playing and suggestibility. So there is plenty of scientific research but no agreement as to the best explanation. SB

Can you prevent your phone being hacked?

You can never completely avoid your phone being hacked. You could stay off the network altogether, but that would defeat the object of having a mobile phone. Even then you are vulnerable to any opportunist who finds your handset lying around.

In the tabloid newspaper phone hacks, imposters accessed victims’ voicemails by guessing the appropriate PIN. So being savvy about your voicemail password and changing it from the default is the first step in foiling the hackers. But it’s not only about protecting your voicemail, as data on your phone could also be at risk. Avoid storing passwords on the device; if you absolutely have to, do so using a secure app. Another security tip is

to switch off the text auto complete function so at least if your phone does fall into the wrong hands, it would be harder to trick the device into betraying your personal info. Finally, steer clear of dodgy apps. GM



Great for preventing hackers, not so good for touchscreens



Penguins don’t need goggles to see underwater



Become an astronaut
and get a fat head!

What effect does zero-g have on our body's fluid?

Earth's gravity means that the blood pressure in your feet is about three times higher than in your head. In orbit, this difference disappears and blood pressure is the same throughout the body. When an astronaut arrives at the International Space Station, their head initially has 20 to 40 per cent more fluid and their legs have about 50 per cent less. Receptor cells in the arteries of the upper body

detect the extra fluid and incorrectly conclude that there is too much blood overall, so the body removes some extra fluid. Over the course of the first few days, this can amount to a litre of fluid less in each leg! Even after this compensation process, blood pressure in the head is still slightly higher than normal and the pressure on the optic nerve can cause long-term vision problems. LV

Why is the Earth's axis tilted?

The Earth, just like all the planets of the Solar System (except Mercury), has a rotation axis that is tilted with respect to its orbit around the Sun. Astronomers propose that this is due to energetic collisions between 'planetesimals'. These small bodies eventually coalesced to form the planets, knocking them off the perpendicular orientation they would naturally have. Uranus is one example of a planet that has a very large axial tilt, which may be the result of a series of such collisions. AG



How does suncream protect you from sunburn?

Opaque sunblocks are effectively paint: inorganic particles of white titanium dioxide or zinc oxide suspended in a heavy oil. The oxide particles form an opaque barrier that reflects visible light and ultraviolet. Clear suncreams use organic compounds, such as phenylbenzimidazole sulfonic acid. This protects from UVB and lets visible light through. Many creams blend inorganic and organic particles to offer good protection. LV



Want to avoid looking like a leathery handbag? Make this your best friend...

How do penguins see clearly underwater?

First, we need to understand a little about our own eyes. In humans, the cornea – the clear surface at the front of the eye – does most of the focusing. The lens only contributes about 10 per cent, and fine-tunes the focus for sharp images at different distances.

Next, we need to look at light. All substances have a refractive index. This refers to the speed at which light travels through them compared to through a vacuum. When we are underwater, the refractive index of the water is too similar to that of our corneas. This means we can't focus as well and our lenses can't adjust enough to make up the difference. Therefore, our vision is blurry

underwater unless we wear goggles. Goggles solve the problem because they introduce a pocket of air between the water and our eyes.

Penguins need to be able to see clearly both on land and in water. They have corneas that are much flatter than ours; this takes almost all of the focusing power away from the cornea, so the lens does most of the focusing. To form a sharp image, a penguin's eye must be able to vastly change the shape of the lens. Penguins' lenses are softer than ours and the muscles can squeeze them up against the opening of the pupil to help them focus in the water. Diving birds also use a similar technique when hunting underwater. LV

SNAPSHOT





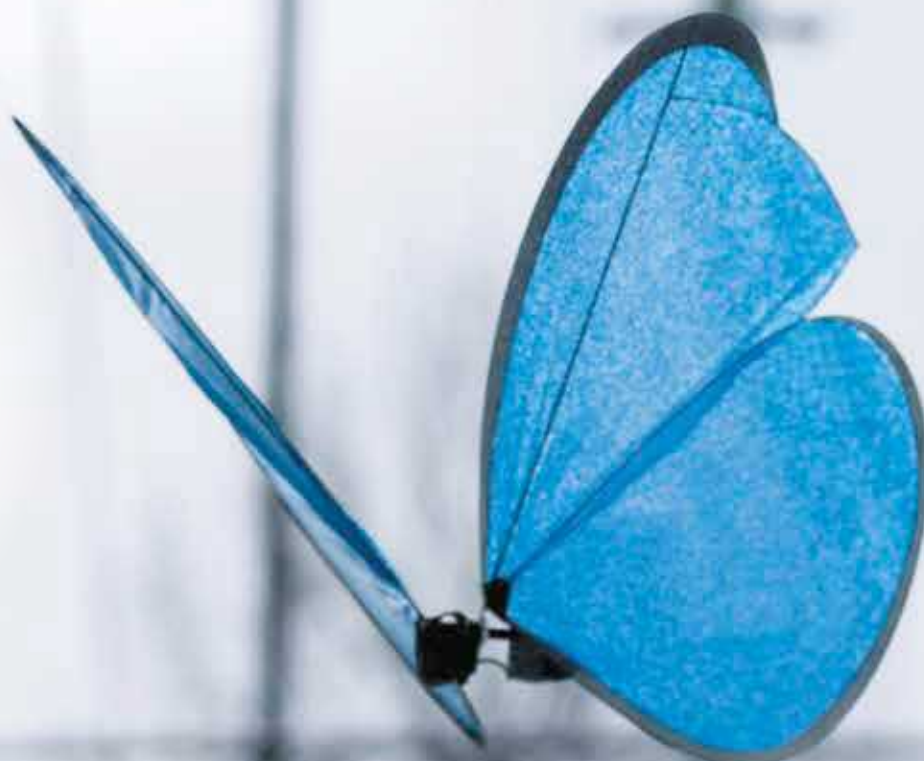
Winged wonders

With their 50cm wingspans, these are not your typical insects. They are eMotionButterflies, one of the latest creations of German automation company Festo.

Their ultra-light wings are made from carbon rods, covered by a film of blue elastic. Each body includes one battery and two small motors, allowing four minutes of flight between charges.

Infrared cameras track the robots by detecting the position of tiny LEDs attached to each butterfly's body. A central computer monitors these positions, instantaneously updating the butterflies' routes to keep them out of harm's way.

"Nature shows us that even animals that are neither strong nor particularly complex can demonstrate coordinated movement as a collective," says Festo's Dr Heinrich Frontzek. "This does not require intricate programming, but only a limited number of simple rules for avoiding collisions." According to Festo, the technology in these bots could be used in a "guidance and monitoring system in the factory of the future".






Cake hole

Occupying a space of 34km³, Tagebau Hambach is the largest open-pit coal mine in Germany. The mine is so vast that it would take 340 Royal Albert Halls to fill it. Gigantic bucket-wheel excavators, each about the length of seven London buses, hew out great chunks of material, exposing cascading layers of sand, soil and coal as they go.

“The excavator wheels have large teeth that dig continuously, throwing the material onto a series of conveyor belts and towards the mine output,” explains Guido Steffen of RWE, the company that runs the mine. “There’s no need for them to separate the materials because nature has already created these distinct soil layers like a piece of cake.”

The vast size of the mine means it can produce up to 40 million tonnes of coal every year, he says.



Salt seller

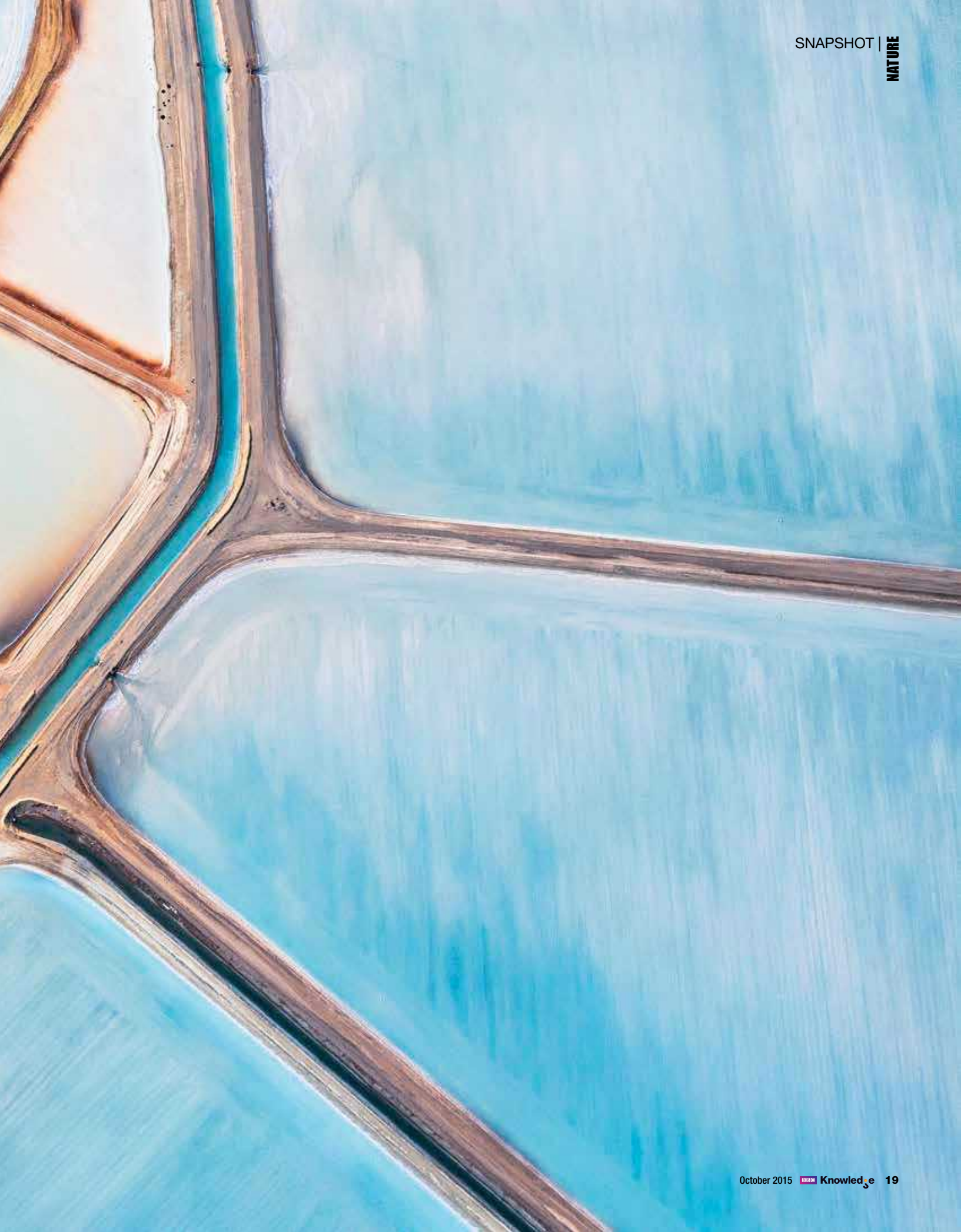
The town of Useless Loop is far more productive than its name suggests. The town is nestled in Western Australia's Shark Bay and is dominated by the strikingly blue evaporative lagoons that are used to harvest vast quantities of salt.

Around 1.3 million tonnes of the stuff is produced each year by evaporating water from an operational area stretching across 87km².

"Shark Bay is extremely hot and dry," says Dr John Statton of the University of Western Australia. "High evaporation rates and low rainfall make it ideal for a solar salt mine." The region's climate and salinity – the seawater is around 50 per cent saltier than in the open ocean – makes it easy to produce salt in huge quantities, while the spotlessness of the water improves its quality.

"Because the environment is so clean and near-pristine, the salt mine is able to extract very high purity salt that commands a premium price," Statton says.

The salt is used for various purposes, including food preservation and the production of caustic soda and chlorine.



DISCOVERIES

IS THERE LIFE ON COMET 67P?

Philae lander will hunt for signs of methane emitted by alien lifeforms

The Philae lander
woke from hibernation
on 13 June 2015

This may not look like the most hospitable place in the Universe, but 67P/ Churyumov-Gerasimenko, the comet visited by the Rosetta spacecraft and its Philae lander, could be harbouring extraterrestrial life.

A number of details have been uncovered about the 'rubber duck-shaped' comet since the Philae probe touched down on its surface last November. It appears to be covered with huge sheets of ice and frozen, flat-bottomed crater lakes, all overlain with organic debris.



Rosetta scientists discussed the mission's latest developments at the Paris Air And Space Show on 17 June 2015

Now, Max Wallis, from the University of Cardiff, and Chandra Wickramasinghe, Director of the Buckingham Centre for Astrobiology, argue that this mixture of ice and organic material could provide an ideal environment for the existence of alien microorganisms. "Rosetta has already shown that the comet is not to be seen as a deep-frozen inactive body, but supports geological processes and could be more hospitable to micro-life than Earth's own Arctic and Antarctic regions," said Wallis. "We consider it highly likely that comets like 67P harboured life in the past and may, even to date, keep viable life in a deep-frozen state."

Any microorganisms that might be present on 67P would require liquid water bodies to exist on the comet, and could also inhabit cracks on the ice created by forces that the oddly shaped, asymmetric comet body generates as it spins. Some types of microorganisms are particularly good at adapting to these conditions and could be active at temperatures as low as -40°C .

Sunlit areas of 67P approached this temperature last September, when the comet was at a distance of some 500 million kilometres from the Sun. As it travels to its closest point to the Sun, at 195 million kilometres, the temperature will rise and any microorganisms that are present would become increasingly active.

The team says the abundance of complex organic molecules found on the comet's surface by the lander Philae also point to the existence of life.

"If they can get the lander Philae working fully, its investigation of methane will help distinguish biomethane [methane produced by life forms] from other carbon-containing gases that could be released simply by solar radiation on the complex carbon compounds," said Wallis. "Investigation by the Rosetta instruments will help too, though the gases will be a little degraded by the time they reach the orbiting craft."

TIMELINE A brief history of the Rosetta mission

2004

Rosetta launches and commences its 6.3 billion kilometre, 10-year journey towards comet 67P. The craft is programmed to go into hibernation on reaching its destination.

JAN 2014

Rosetta receives a signal to wake up. Soon afterwards, it sends its first images of the comet back to Earth. Scientists are surprised by the comet's unusual 'rubber duck' shape.

NOV 2014

Rosetta sends Philae, its lander, towards the comet. Philae sends back reams of unprecedented data and images back to Earth, but having landed in shadow, powers down after just 60 hours.

JUN 2015

With the Sun back in the sky from Philae's point of view, the lander powers back up on 13 June and resumes communication with Rosetta. New objectives now await...

GOOD MONTH/ BAD MONTH

IT'S BEEN GOOD FOR:

BACON LOVERS



If you love chowing down on a bacon sarnie but aren't so fond of the effect your culinary habits have on your waistline, you may be in luck. A team of scientists in South Korea has used gene-editing technology to create a new breed of 'double-muscled' pigs. The porkers could be used to make extra-lean bacon.

FANS OF CAT VIDEOS

It turns out all that time we have spent watching funny felines on YouTube wasn't wasted after all. A study at Indiana University has found that watching Maru, Grumpy Cat and Lil Bub boosted viewers' energy and reduced levels of anxiety, sadness and stress. The results suggest that online videos may one day be used as a form of low-cost pet therapy.

IT'S BEEN BAD FOR:

BOYS



When times are tight, it's better to be female. Researchers in the US have found that in time of economic hardship parents are more likely to spend a larger proportion of their money on daughters. The effect is more pronounced when the daughters are getting closer to childbearing age, suggesting the parents want grandchildren, they say.

NIGHT OWLS

Those with poor sleep habits such as inconsistent bedtimes and short sleeping periods are more likely to succumb to impulsive desires, inattentiveness and questionable decision making, a US study has found. The effect is thought to be due to depleted energy reserves making us more likely to plump for the easier option or task.

10 DISCOVERIES THAT WILL SHAPE THE FUTURE

10 Life extension pill

Blocking the Ras protein's effects could be the answer to a longer life

A drug that dramatically extends your lifespan could be on pharmacy shelves in as little as 10 to 20 years, according to scientists at University College London. Fruit flies given the skin cancer drug Trametinib lived 12 per cent longer, on average, than a control group.

The cancer drug delayed ageing by limiting the effect of a protein called Ras. The researchers are now moving onto experiments with mice and hope to develop a drug for humans without the side effects of traditional cancer treatments.

9 Water-saving grass

US Golf courses need 750 billion gallons of water every year to look their best. Using wastewater instead of clean water on links and other sports fields is the way forward. But wastewater contains salt, which plants don't like. Researchers at Rutgers University tested 142 varieties of perennial ryegrass, bred to have different genetic traits. **The results showed it's possible to selectively breed grass to produce varieties that have a high tolerance to salt.**



Some grasses turn brown when in contact with salts, while other strains retain their green colour

8 Artificial mosquito blood

Putting out food for mosquitoes might not seem like the smartest idea. Yet artificial blood developed at the University of Kentucky may prove hugely important in the fight against mosquito-borne diseases like malaria, dengue and yellow fever.

The 'blood' can be laced with a mozzie-sterilising bacterium and put out as a free banquet.

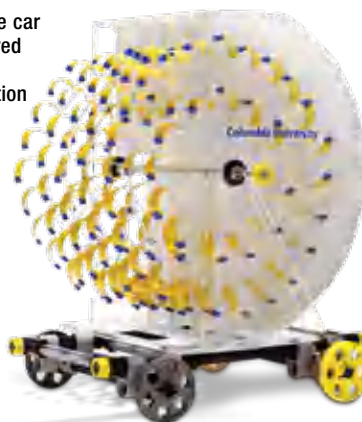


Your days are numbered, Mrs Mosquito...

7 Evaporation engine

Nature's biggest untapped power source could be evaporation. Now, Columbia University scientists are building **engines and generators that harness this renewable resource.** They use *Bacillus* spores, which expand and contract as they absorb moisture from the air. This movement can then be used to drive turbines. Find out more at bit.ly/evaporation_power

This little car is powered by the evaporation of water



6 Transplantable body clock

Circadian rhythms help your body regulate time, but they can get out of sync. **A genetically engineered, transplantable body clock could help treat problems like jet lag.** Harvard University researchers extracted a protein circuit from cyanobacteria, which has a natural rhythm, and transplanted it into *E. coli*, which doesn't. The *E. coli* could then 'blink' by switching a fluorescent marker on and off every 24 hours.



Cyanobacteria has a natural rhythm

5 Brain mesh



Before you can create a cyborg, you need a means of carrying electrical signals to and from the brain. Now, Harvard scientists have successfully injected an electronic mesh into the brain of a mouse. The mesh was initially rolled up in a syringe, but unfurled and melded with brain tissue once injected. **In future, it may help treat neurodegenerative disorders in humans.**

4 Invisible security tags

A team at Missouri University has created **microscopic colour images by making tiny perforations in a multi-layered material.** The tech could be used for creating advanced security tags that are difficult to replicate. the technique involves punching tiny holes in a sandwich-like material made from silver and silica, and mimics the way that the wings of butterflies and birds create colour. Different colours can be produced by changing the size of the holes.



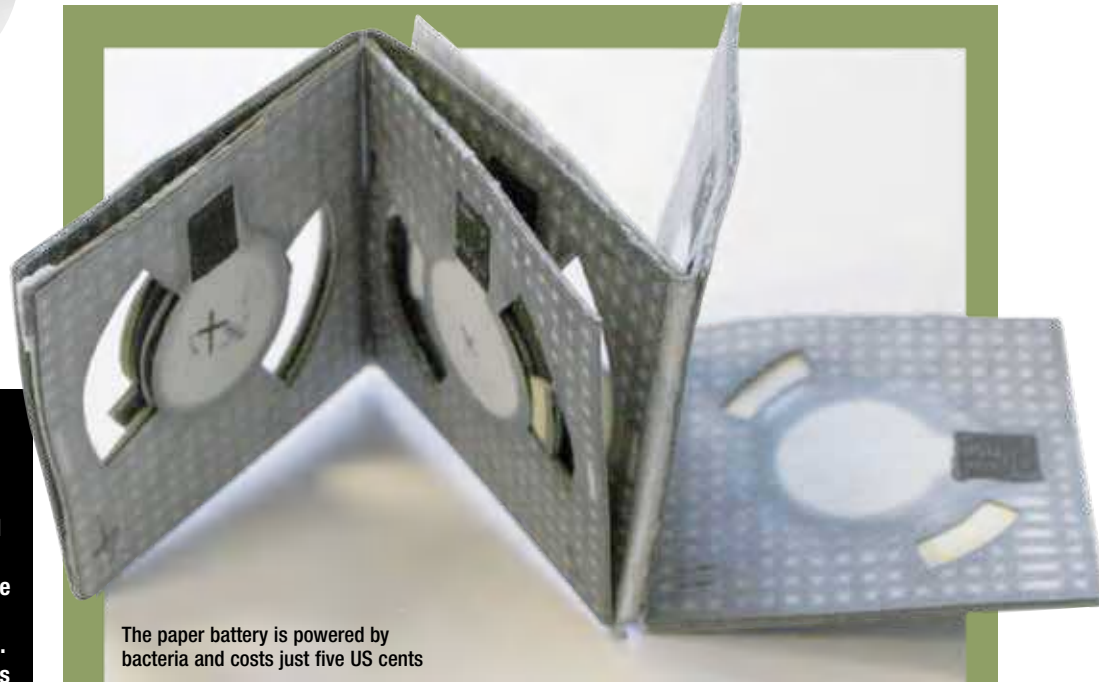
This logo measures just 50 micrometres across

2 Robot tentacles

Picking up tiny, fragile objects without causing damage can be something of a challenge for a set of robot pincers. **So a spiralling tentacle developed at Iowa State University could be just the job for manipulating human tissue or blood vessels.** The tentacle is an 8mm long tube with a diameter of less than 0.4mm. It is made of a class of rubbery polymers called elastomers. Air pumped into the tube causes it to coil, allowing it to gently squeeze the object it's picking up without causing any damage.



While flattered by the attention, ant started to feel that the humans had become a little clingy



The paper battery is powered by bacteria and costs just five US cents

3 Paper battery

A paper battery constructed using origami techniques has been unveiled at Binghamton University in New York State. The battery requires just one drop of bacteria-containing liquid such as wastewater. It generates energy from

the respiration of the microorganisms present in the water. It supplies only a few microwatts, but that's enough to **power paper biosensors that have been developed to detect diseases like HIV and E. coli in developing countries.**

1 Smart camouflage

Squid and octopuses use cells called chromatophores to create colours and patterns on their skin. Now, researchers at the University of Bristol have made a material that mimics this effect. **Soldiers could use the fast-changing, adaptive camouflage on covert missions.** It's made from a rubbery material that can be electrically controlled.



Three artificial chromatophores created by the team

PATENTLY OBVIOUS

Inventions and discoveries that will change the world

THE RIGHT TROUSERS

If you've ever envied Iron Man's suit, here's one for you. Designed to help the elderly or injured walk, Samsung's robotic suit is an exoskeleton for the legs. Two electromyogram sensors detect electrical activity in the muscles, helping to determine the wearer's position in the walking cycle. Motors then spring into action, providing power to the legs. Let's hope it's portable enough to haul up mountains – we could do with some extra help when hiking.

Patent application number:
US 20150134080

EAR EAR

Forget fingerprints: how about using your ear to unlock your phone?

A system from Amazon uses the unique shape of a person's ear to identify them, unlocking the phone when they hold it to their lug. The technology will be able to determine which ear you're holding it to – adjusting the positions of buttons to suit your left or right hand – and even ramps up the speaker volume if it detects your ears are covered by hair or a hat. Handy if you're going to a party as Sherlock Holmes...

Patent number: US 9,049,983



The ICAROS exercise machine simulates flying to help you work out

FLYING FIT

Let's face it, exercise can be a dull activity. Those endless miles running on the treadmill; those countless hours sweating in a muggy, overcrowded gym. Imagine if you could exercise while flying through outer space or soaring over a faraway land.

That's the experience offered by ICAROS, a combined fitness and gaming device developed by a team in Germany. The workout station is an unusually shaped cradle that pivots on two different axes. You position

yourself on the machine by adopting a Superman pose, using the leg and arm rests to support your weight.

ICAROS then acts as your gaming controller. It allows you to steer your way through a flying simulator, which is beamed to you via a standard pair of VR goggles. In order to avoid crashing, you'll have to stretch and strain your body, giving you an all-over workout. You'll feel like Peter Pan, only a bit older and a lot more sweaty.

Patent pending

1 MINUTE EXPERT

Bacterial fight clubs



Bacteria go head-to-head in the laboratory



ER... ARE YOU SURE YOU'RE SUPPOSED TO BE TALKING ABOUT THAT?

Don't worry – it's nothing to do with Tyler Durden. It's a method of searching for new drugs that was created by chemists at Nashville's Vanderbilt University.



TELL ME MORE.

The work is based around secondary metabolites – compounds released by bacteria to fight off organisms. Lots of antibiotics and anti-cancer compounds are either secondary metabolites or their derivatives.



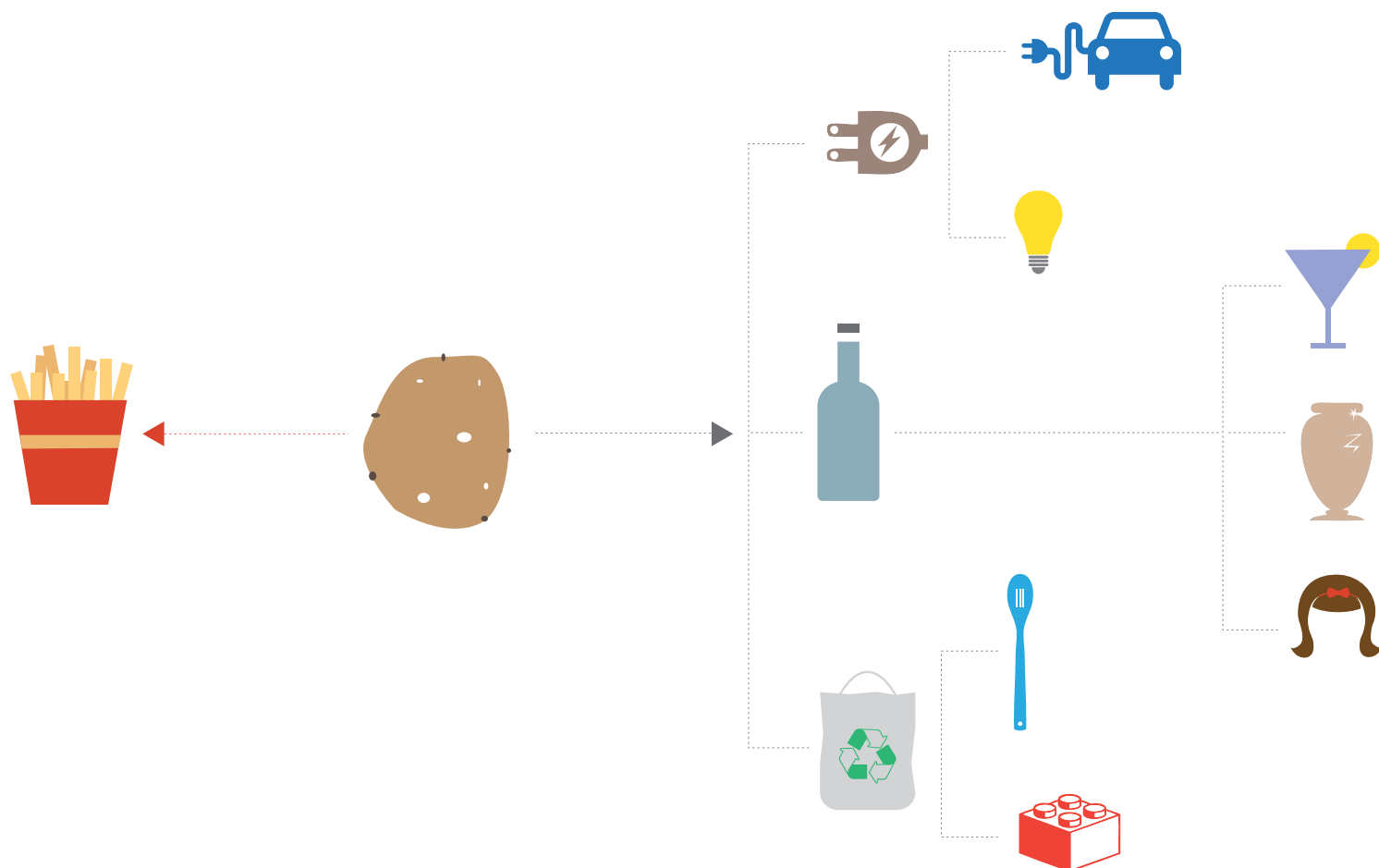
SO WHERE DOES THE FIGHTING BIT COME IN?

Analysis of microbial genomes suggests that each of the 150,000 distinct species of bacteria contain the blueprints for hundreds of secondary metabolites. The problem is, getting the bacteria to produce them can be tricky. By pitting microorganisms against one another in controlled 'fight clubs', the researchers were able to trigger the release of secondary metabolites.



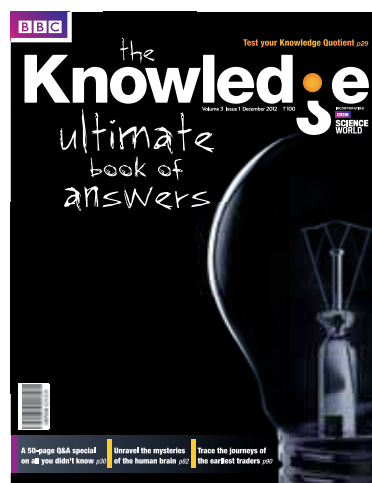
HAVE THEY FOUND ANY NEW DRUGS?

It's still early days but one new compound, dubbed circomycin, has a structure similar to current antibiotics and has already demonstrated tumour-killing qualities.




THERE'S MORE TO EVERYTHING.
EVEN POTATOES.

KNOW YOUR STUFF.



NASA's Valkyrie is a Boston Dynamics Atlas robot that's been customised for use in space



A close-up of a white robotic hand with blue joints, holding a small, round, metallic object. The hand is positioned on the left side of the frame, partially obscuring the large title text.

ROBOTS LIKE US

Opening a door or driving a vehicle near you soon, robots are starting to perform the everyday tasks we take for granted. Duncan Graham-Rowe meets our machine counterparts ►

Anyone who found themselves at the Homestead Speedway in Florida in December last year could be forgiven for thinking they had wandered onto the set of a George Lucas blockbuster. In the middle of the track a heaving crowd gathered to watch futuristic-looking robots take on a series of challenges while crews armed with banks of video cameras recorded their every move.

The robots were gathered there to duke it out in the DARPA Robotic Challenge Trials. Teams from prestigious institutions such as NASA and MIT competed against each other in a series of tasks specially designed to test their robots' mettle. These included climbing a ladder, connecting a hose to a standpipe and turning it on, driving a vehicle, using a tool to break through a concrete wall and, that all time classic, opening a door to enter a building.

Although perhaps trivial to us, tasks such as those in the DARPA challenge present huge difficulties for robots and their designers. The idea of tests such as these is that eventually we may be able to send robots into hazardous environments to perform dangerous tasks in place of humans. Similarly it could enable domestic robots to drive your car to the shops, do the ironing or answer the phone. This is why DARPA created the challenge, dangling a \$2 million prize before the eight qualifiers when they meet again later this year for the final. And it's also why game-changing technology companies like Google are now getting involved. Google recently acquired Boston Dynamics, a Massachusetts-based start-up that has developed some of the most sophisticated robots in the world, including BigDog and Atlas.

Humanoid droids

Rather than resembling a dustbin-on-wheels like the creations of yore, the majority of the robots on display at the DARPA challenge were remarkably human in appearance. They stand on two legs, have two arms with articulated shoulder joints and even have dexterous human-like hands. Spurring this revolution is the recognition among roboticists that our world is designed around the human form and therefore needs robots that are adapted to this kind of environment. So instead of redesigning our entire world to accommodate short, stumpy, wheeled robots that require a postgraduate degree in computer science to command, we're now seeing radical advances. These will make robots altogether more human-like so that they move, interact, and even think like us.

Honda's Asimo is the poster boy of the robotics world – it can run at speeds of 6km/h (3.7mph)



HOW THEY MOVE

Robots are finally starting to master something we take for granted: using two legs

To appreciate the advantages that legs offer over wheels, you have only to examine the dust accumulating on the stairs of any household cleaned by a Roomba robotic vacuum cleaner. The fact is our world is filled with all manner of uneven, compliant, soft and even moving surfaces that pose huge challenges for the humble wheel.

"Legs are good because they provide locomotion on irregular terrain," says Marc Raibert, founder of Boston Dynamics. "People and animals use their legs to go almost anywhere on Earth, while wheeled and tracked vehicles are limited to travelling on relatively smooth and flat surfaces, such as roads."

In fact, even wheeled robots designed specifically to tackle rugged terrain have been known to get into trouble, such as NASA's Spirit Mars rover, which ignominiously got stuck in a sand trap on the Red Planet in 2009 and, as far as we know, remains there to this day.

Hardly surprising then that roboticists have long been trying to emulate our ability to walk, with varying degrees of success. For although there have been some highly nimble six-legged insectoid robots and four-legged mammalian 'bots, among others, when it comes to two legs, staying upright has proved far more

difficult. The simple reason for this is that it is possible to remain stable when you have more than two legs, even with no power. In contrast, it didn't take much to push over early bipedal robots when they were standing still, let alone when walking on an uneven surface.

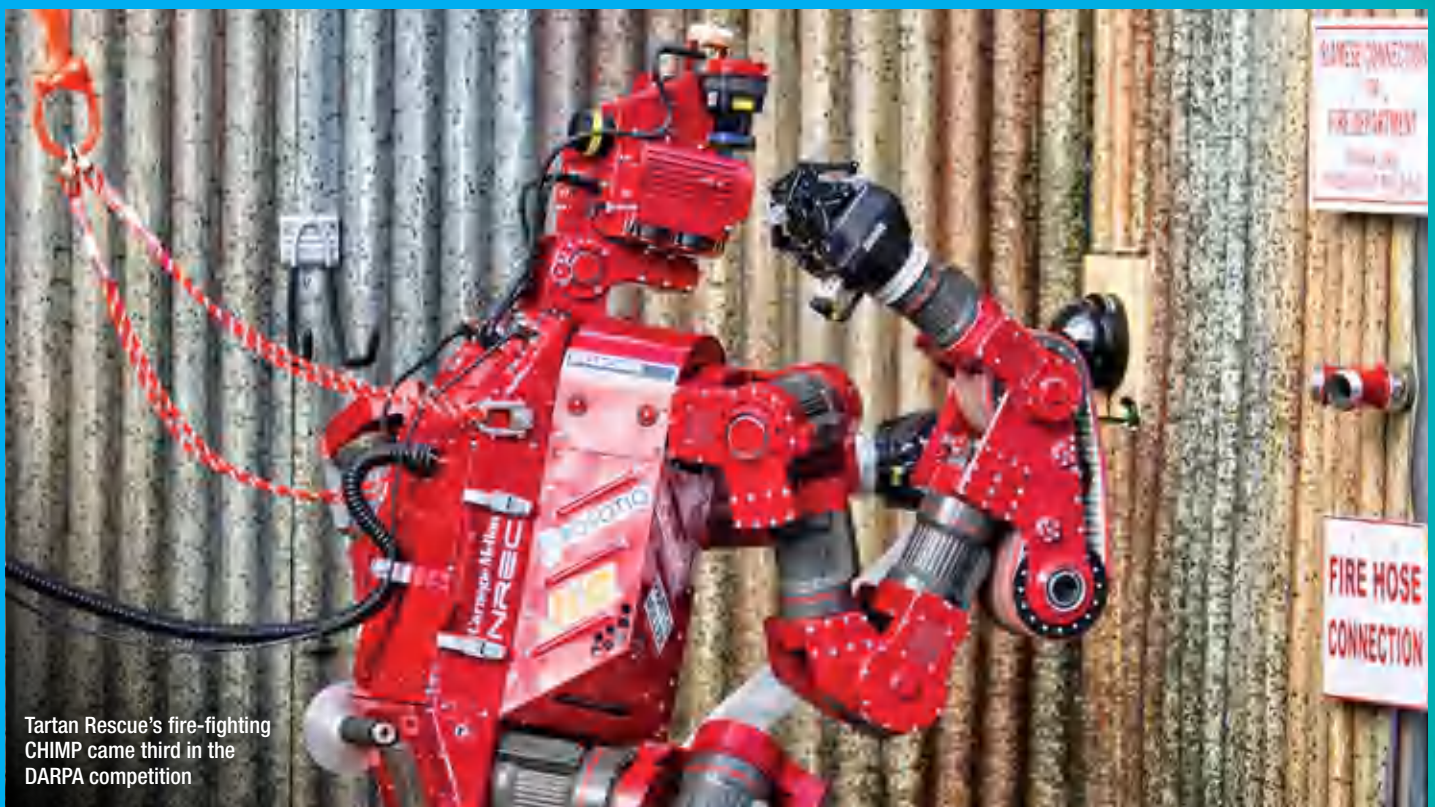
TWO-LEGGED RACE

In recognition of the difficulty of this problem, a decade ago powerful technology companies like Honda and Sony took up the challenge and developed two-legged robots, such as Asimo and QRIO (pronounced 'curio'). With millions of dollars injected into their development, the aim with these ambassador robots was to demonstrate the technological prowess of their makers, by reaching this sacred milestone and effectively 'solving' bipedal locomotion.

To some extent they were successful, creating robots that could walk up and down stairs, across uneven surfaces, run, dance and even do some tai chi. ►



The Russian SAR-401 robot will work on the International Space Station



Tartan Rescue's fire-fighting CHIMP came third in the DARPA competition

However, as impressive as these demonstrations were, they came with certain caveats. These robots were essentially designed to remain stable at all times, which meant that if at any moment you were to pause one of these robots they should, in theory, stay upright. To make this possible both Asimo and QRIO were designed to walk in a crouching manner with their knees bent awkwardly to keep their centre of gravity low, giving them a constipated appearance.

But recently, fresh inspiration has sprung from an altogether more biological approach. Research groups and companies like Boston Dynamics have started to make real

advances in mimicking the dynamic way in which living creatures move. Humans, for example, are rarely in a truly stable vertical position, even when standing. Instead we make almost continuous adjustments to stay upright. And when we walk and run we are almost in a constant state of falling forward and catching ourselves as we move.

This can be partly achieved by loading in lots of sensors to enable a robot to make the necessary corrections and adjustments in real-time. But Boston Dynamics has found other benefits from paying close attention to the dynamic way in which creatures move. In 2012 its four-legged Cheetah robot lived

up to its name by breaking the world speed record for a legged robot. Running at 28km/h (18mph), it smashed the previous record of 21km/h (13mph) set in 1989. This was made possible by working with experts to identify traits that enable real cheetahs to achieve high speeds, most notably by designing a flexible spine that enables the animal to increase its stride without having to take longer steps.

ATLAS WALKS

Applying similar insights to two-legged systems has also enabled Boston Dynamics to develop Atlas, a bipedal robot capable of a broad range of human-like movements, including walking over uneven surfaces and performing a host of gymnastic-like movements.

This may sound familiar, but what sets it apart from the likes of Asimo and QRIO is the fact that Atlas doesn't need to 'know' its environment in advance in order to map out choreographed movements. Instead it is able to sense its environment as it moves, using a combination of stereo cameras and LIDAR, the laser equivalent of

radar. Moreover, its movements are dynamic. This means that it is able to respond to changes in the environment. And because it moves dynamically, constantly assuming it is off-balance and making adjustments to its actuators accordingly, it is able to compensate and stay upright even when taking an impact mid-stride, much like we can.

In terms of robotic evolution this is quite simply huge, and perhaps even on an equivalent scale of when early humans first rose up from four legs onto two. Raibert remains modest about his achievements. "I make no distinction between two legs and four legs," he says. "Almost all the problems are fundamentally the same and almost all the solutions are fundamentally the same, at least for really effective solutions."

All it takes, says Raibert, is the combination of computation, sensing, a sophisticated mechanical system and an understanding of the physics of the problem. Although, he's quick to point out that it is not perfected. "Atlas is able to walk in

"If you compare Atlas's capabilities to those of a human, there are still many opportunities for improvement"

Marc Raibert, founder of Boston Dynamics



Boston Dynamics's Cheetah is the fastest robot on four legs, reaching speeds of 28km/h (18mph)

certain circumstances and exhibits lots of promising results. But if you compare its capabilities to those of an active human, there are still many opportunities for improvement," says Raibert.

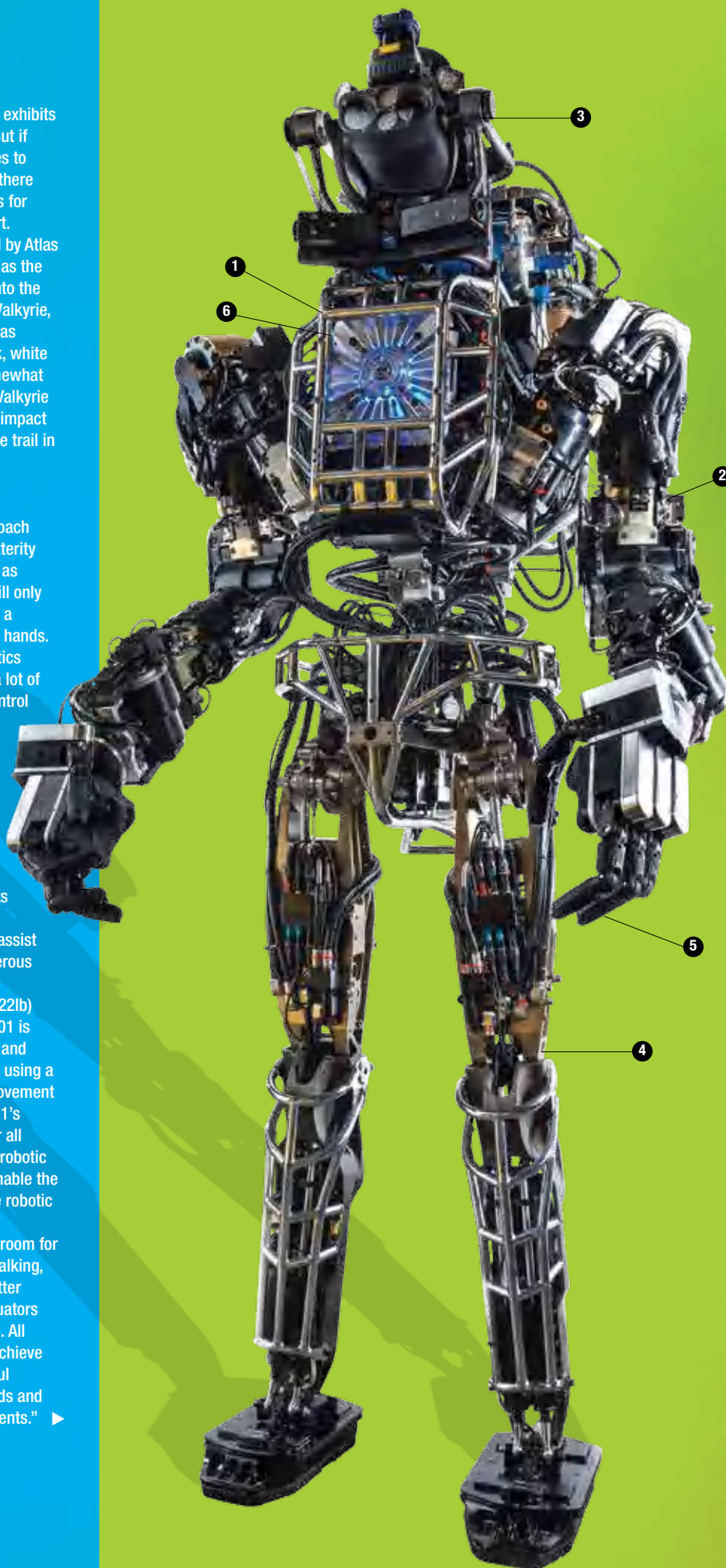
NASA was so impressed by Atlas that it acquired one to use as the basis for their own entry into the DARPA challenge. Named Valkyrie, the robot consists of an Atlas exoskeleton clad in a sleek, white protective outer shell. Somewhat embarrassingly for NASA, Valkyrie failed to make much of an impact in the tests and finished the trail in second to last place.

TOUCHY FEELY

Besides walking, this approach is likely to improve the dexterity of robots too, which is just as important. After all, legs will only get you so far. To be useful a robot also needs arms and hands. Decades of industrial robotics means that we now have a lot of experience with how to control and manipulate objects using a robotic arm. And now there are even highly realistic five-fingered robotic hands, like those attached to the SAR-401, a humanoid telepresence robot developed in Russia and that will join astronauts on board the International Space Station this year to assist them in carrying out dangerous tasks in space.

Capable of lifting 10kg (22lb) under Earth gravity, SAR-401 is both strong and dexterous and can be controlled remotely using a special glove. Whatever movement the wearer makes, SAR-401's hands will mimic it. But for all their deftness, what these robotic hands lack is sensors to enable the astronauts to feel what the robotic fingers feel.

But then there's always room for improvement, even with walking, says Raibert. "We need better power supplies, better actuators and better control systems. All need to work together to achieve robots that can travel useful distances, carry useful loads and work in complex environments." ►



ATLAS

Meet the most sophisticated robot in the world

1

CRUMPLE ZONE

Metal cage-like structures around its limbs provide crash protection to its more vulnerable sensors and motors. After all, even people fall over occasionally.

2

JOINTS

A total of 28 hydraulically-actuated joints with high-performance position and force control is what keeps Atlas upright and able to move, although currently its power supply comes via a tether.

3

SENSORS

To help it move around its environment, Atlas comes with a head-mounted sensor package complete with LIDAR (a laser version of radar), stereo cameras, dedicated sensor electronics and perception algorithms.

4

BUILD AND BALANCE

Standing at about 1.9m (6ft 2in) tall, Atlas has been built to resemble a full-sized adult, with joints that provide near-human movement of limbs to enable walking, running and even calisthenics.

5

GRIP

Although Atlas's three-fingered hands are more like claws, its modular wrists allow for them to be replaced with hands made by different manufacturers.

6

COMPUTER

Atlas's chest houses a computer, cooled with a fan, that governs motor control and sensors. Commands are sent via a wired link.

HOW THEY THINK

An intelligent robot will have to match the power and efficiency of the brain

Perhaps one of the biggest motivations to make robots more like us is the potential for them to be smarter. After all, if you want intelligent robots then it makes sense to take inspiration from the most sophisticated computer that we know of – the human brain.

It's all very well being able to calculate Pi to a billion decimal places, but when it comes to tasks that require lots of pieces of information to be processed at the same time, traditional computers really struggle. This is perhaps most evident in pattern recognition tasks, such as the human ability to recognise a face even though its appearance might have changed over the years.

A DIGITAL BRAIN

One solution has been proposed by Henry Markram, director of the Center for Neuroscience and Technology at the Swiss Federal Institute of Technology, in Lausanne.

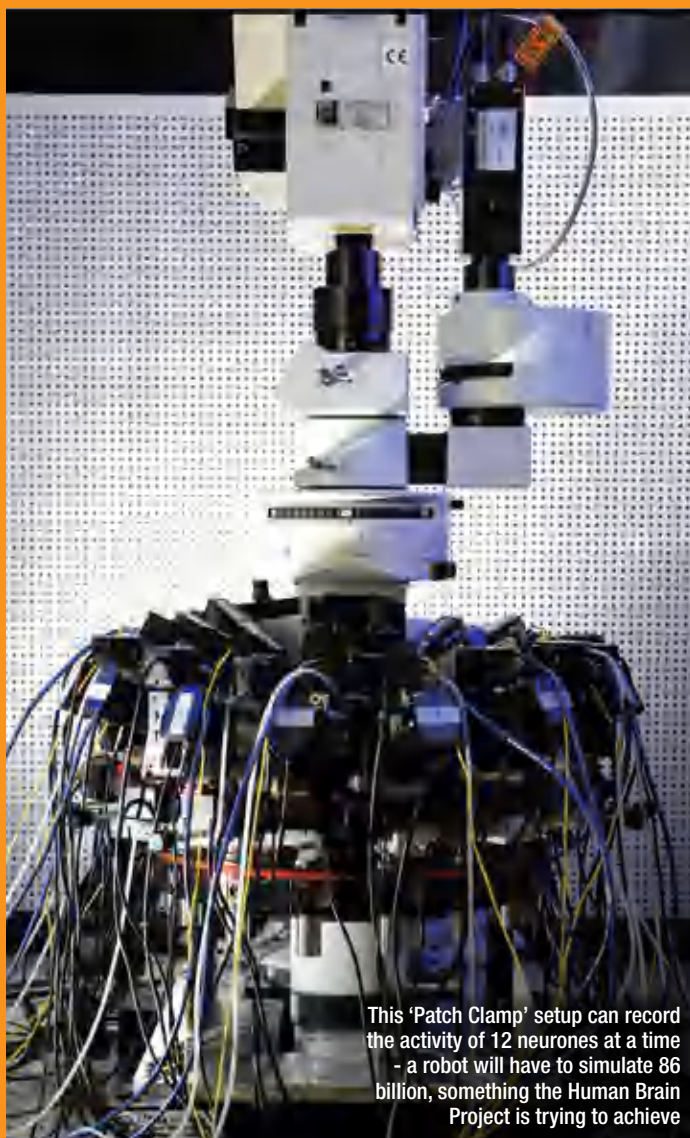
Markram heads up the Human Brain Project, a bold effort to create a supercomputer simulation of the precise architecture, function and connectivity of the entire human brain. That's all 86 billion neurones as well as the 100 trillion

connections that link them together.

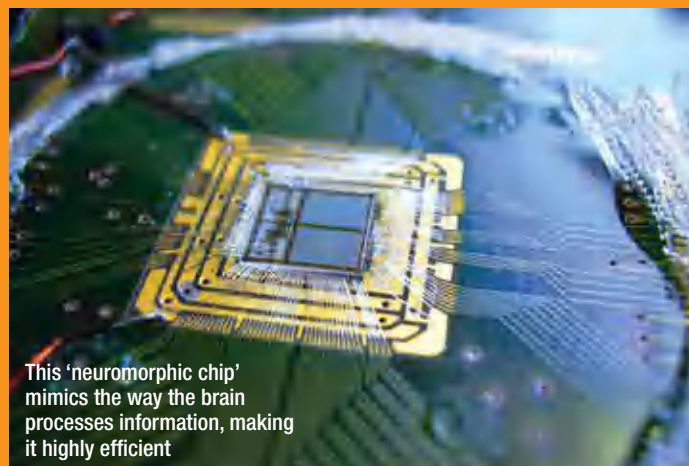
The most powerful supercomputers today are capable of performing computational processes on the order of petaflops – that's a thousand trillion floating point operations a

“A lot of the brain’s appeal is in how little power it uses. So what is it that makes them so effective and so efficient?”

Kwabena Boahen, a bioengineer at Stanford University, California



This 'Patch Clamp' setup can record the activity of 12 neurones at a time - a robot will have to simulate 86 billion, something the Human Brain Project is trying to achieve



This 'neuromorphic chip' mimics the way the brain processes information, making it highly efficient



A simulated neural network courtesy of the Human Brain Project

second. According to Markram the human brain project will require computers that are a thousand times more powerful and enough power to run a small city the size of Brighton. Hardly practical for just one robot brain.

MINDS LIKE OURS

There are, however, other approaches. NeuroGrid, a one million neurone 'neuromorphic' computer developed by Kwabena Boahen, a bioengineer at Stanford University, in California, also uses this so-called neuromorphic approach to simulate brain activity in computers. But instead it uses the analogue – that is, non-digital – characteristics and properties of the transistors and other components in the circuits. This approach allows it to simulate a million neurones and six billion synapses connecting them, using very little power, much like a biological brain. "The main motivation for this approach is that the brain does a lot more than computations," says Boahen. "A lot of its appeal is in how little power it uses. What is it that makes them so effective and so efficient? This is the secret of the brain."

But most intriguing of all is the issue of intelligence. The neuromorphic approach doesn't only suggest that we could create robots smart enough to show human-like processing power. It also brings with it the prospect of scaling up to something even more complex than the human brain and perhaps, just perhaps, more intelligent.



Henry Markram is trying to reverse engineer the human brain



The real Ishiguro is on the left, the robot is on the right... er hang on, it's the other way round

HOW THEY INTERACT

The endgame for robotics is to have them become a seamless part of human society

Let's face it, it doesn't matter how smart, nimble or even cute you make a robot, if people can't figure out how to use it easily, then very quickly they'll lose interest. The best way to avoid this, then, is to throw away any notions of programming or instruction manuals, and instead design them to interact intuitively with people as if they were people. This presents roboticists with a serious hurdle. Human communication is hugely complex and nuanced, and full of countless subtle non-verbal gestures, references and facial expressions, all of which are dripping with meaning.

Arguably, no one is more familiar with this than Hiroshi Ishiguro, an engineer and roboticist at Osaka University, Japan, who is famed

for creating robotic doppelgängers of people that are so realistic they are hard to tell apart. "My research is not only to develop robots, but also to unravel the nature of human beings themselves. This is because many aspects of what it means to be human are still shrouded in mystery. Therefore, no matter how far they are from having concrete practical uses, we are spending enormous funds to develop real androids," he says.

A HUMAN TOUCH

However, the level of realism and detail involved with these robots, which Ishiguro calls Geminoids, although extremely impressive, may not be necessary or even appropriate. In his latest research Ishiguro has gone from one

extreme, convincing us of how realistic robots can appear, to the other, creating robots with only the most basic human features and relying upon us to do the rest of the work.

"My research is focused on Telenoid, which was designed to appear and to behave as a minimalistic human. At the very first glance, one can easily recognise the Telenoid as humanoid, but it appears as both male and female and both old and young," says Ishiguro.

At first glance Telenoid looks like a pale, white, truncated head and torso; with small stumps for arms, and a simple, almost ghostly, human face with little more than eyes, nose and mouth. These robots are designed to act as a form of communications telepresence, ▶

If you really want to connect with the person on the end of a phone, why not carry the androgynous Telenoid around with you?



with motors within to form simple expressions, enabling people to converse and interact with someone far away via the robot.

Ishiguro's belief is that even with its simple design and limited expressions, people are able to easily recognise whether they are talking to a male or female, old or young. That is, Telenoid will serve as a blank template for people's minds to fill in the detail themselves. An experimental study involving elderly people in Denmark is currently underway to see how this novel form of

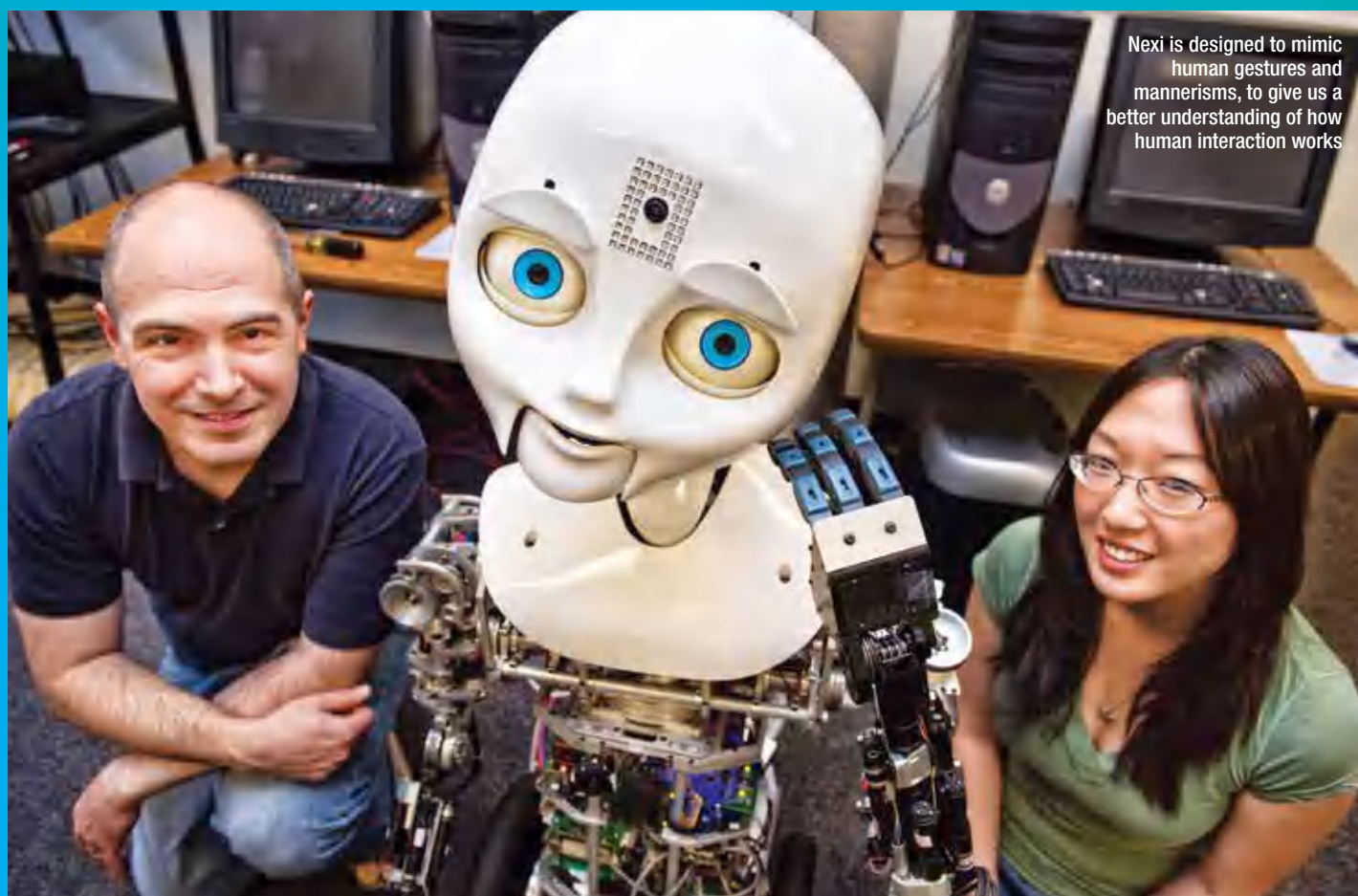
communication medium fares, says Ishiguro.

A HUMAN TOUCH

A similar approach proved successful more than a decade ago with Kismet, a Gremlin-like robotic head. It used exaggerated baby-like facial expressions to emotionally blackmail people into socially engaging with it, for instance by looking sad whenever someone stopped playing with it, or bored if they kept doing the same thing again and again. The brainchild of MIT's Cynthia



Ishiguro's Telenoid can interact with you using a variety of human expressions



Nexi is designed to mimic human gestures and mannerisms, to give us a better understanding of how human interaction works

“My research is not only to develop robots, but also to unravel the nature of human beings themselves”

Hiroshi Ishiguro, engineer and roboticist at Osaka University, Japan

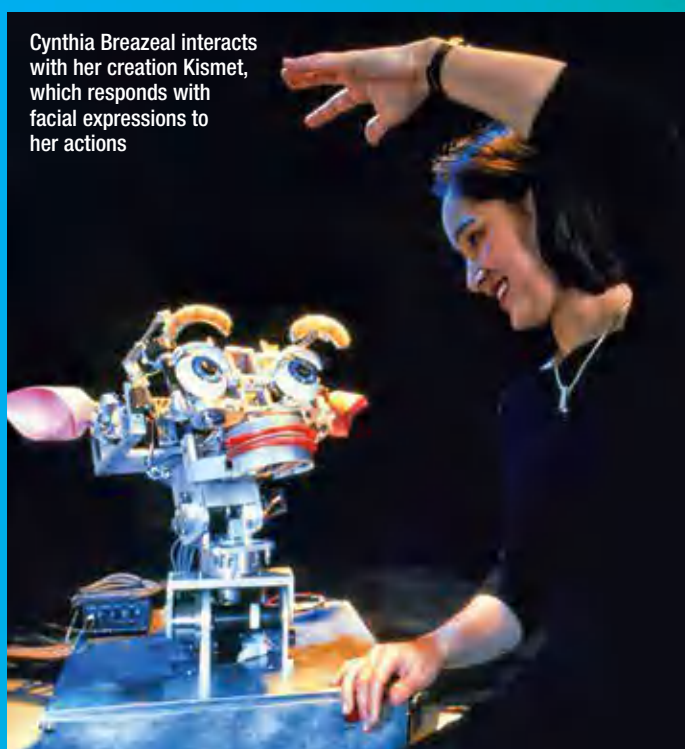
Breazeal, this work showed not only that we are suckers for a cute face, but also that it was possible to exploit the way we are hardwired to respond to the needs of infants in order to teach a robot.

Today Kismet has evolved into a sleeker, less animalistic and more mobile 'bot called Nexi, which also has arms to enable it to interact with its environment. This combination makes it possible to train Nexi to carry out different complex social tasks, such as 'joint attention', where two or more people (or robots) use gestures or eye

gaze to indicate what they are referring to.

Such skills are the building blocks of human interaction and so should help ensure, for example, that robots don't simply look at the end of our finger whenever we point at something, as some dogs frustratingly tend to do. It is like finishing school for robots, teaching them the social graces that will help them get by in the world, and make them just a little more like us. 🍷

Duncan Graham-Rowe is a science and technology journalist.

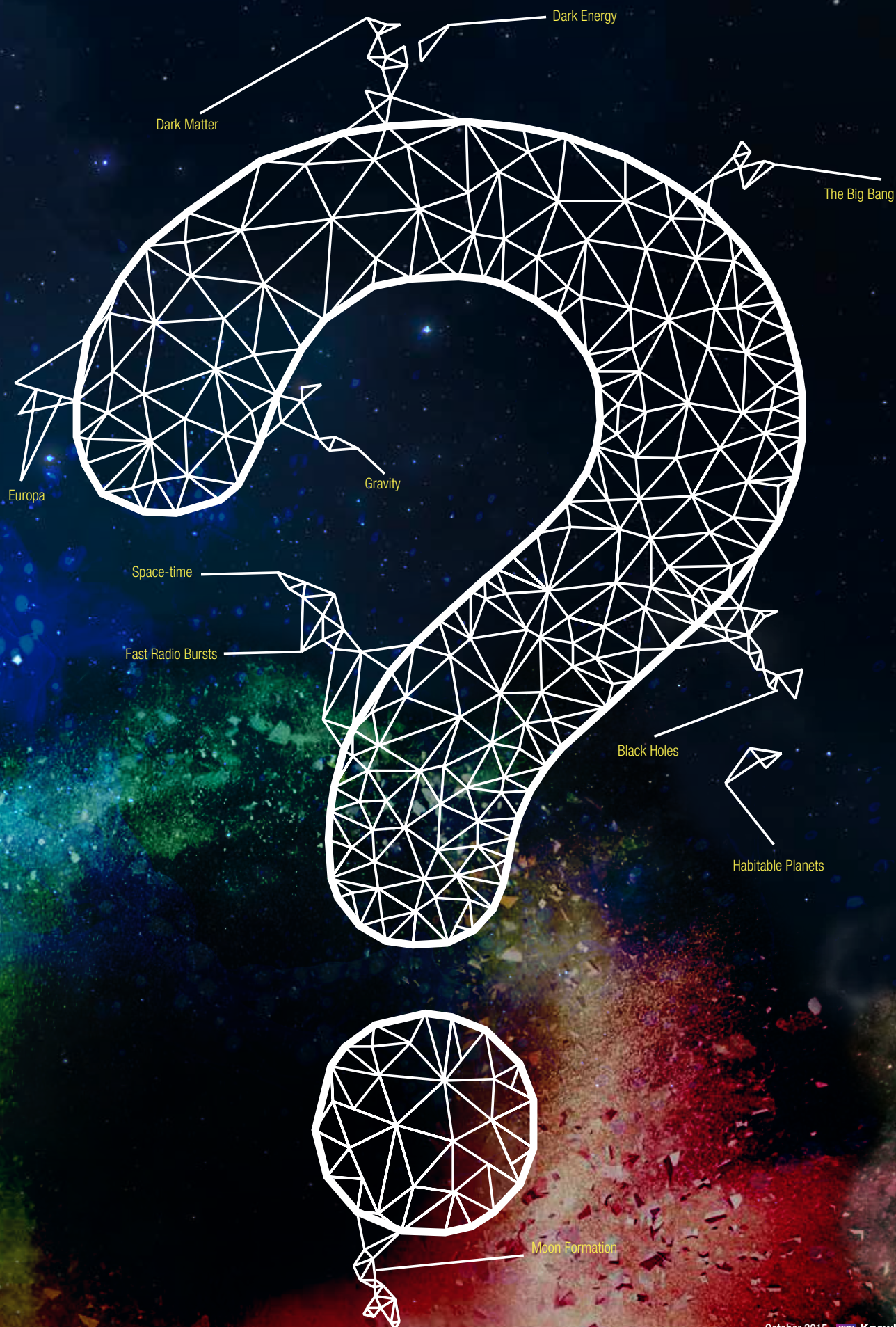


Cynthia Breazeal interacts with her creation Kismet, which responds with facial expressions to her actions

The background of the entire page is a cosmic scene. On the left, a bright green nebula or gas cloud is visible, with a beam of light shining from it towards the center. The rest of the background is a dark, deep blue space filled with numerous small, reddish-brown fragments or debris, resembling a cosmic dust storm or the aftermath of a collision. The overall effect is one of mystery and vastness.

THE UNKNOWN UNIVERSE

We still have a long way to go when it comes to
untangling the mysteries of the cosmos.
Stuart Clark takes a look at some of the most
perplexing questions yet to be answered by science ►



10

How did it all begin?

Cosmologists talk about the Big Bang, but they have no idea what it was. "We are sure that the early phase of the Universe was hot and dense," says Prof Tim O'Brien, an astronomer from Jodrell Bank, University of Manchester. "But what triggered the Big Bang is still very much open for investigation."

In March 2014, astronomers using an instrument called BICEP2 thought that they had seen evidence for a colossal increase in the expansion of the Universe at the moment of the Big Bang. This would fit theoretical ideas called inflation. Sadly, it turned out to be space dust contaminating the signal.



The BICEP2 lab is located at the South Pole

9

What are fast radio bursts?

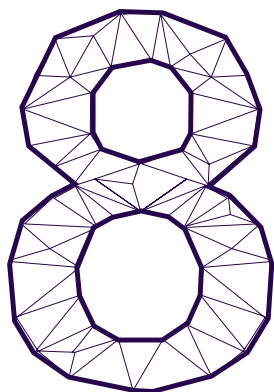
Fast radio bursts have the whole radio astronomy community scratching their heads at the moment. Just a dozen or so of the mysterious electromagnetic pulses have been discovered since the first one was detected in 2001. Each lasts just a few milliseconds, yet carries as much energy as the Sun releases in a month. "We

really have no idea at all what these things are," says O'Brien.

Various suggestions have been made, including exploding stars, evaporating black holes and even alien signalling devices. Calculations show that there could be as many as 10,000 of these radio bursts taking place every single day, but they still remain a mystery.



Magnetars, a type of star, are one proposed source of fast radio bursts



What is the space-time continuum?

"The space-time continuum is the pinnacle of cosmological achievement in the last century," says Dr Andrew Pontzen, cosmologist at University College London. The trouble is, nobody understands what it actually is. When Einstein developed General Relativity, he introduced it as a mathematical coordinate system. But what did it represent in reality?

The maths suggested it was a malleable substance in which the celestial objects are suspended, but General Relativity provides no real insight into its physical nature. It could be made of incredibly tiny particles like a beach, which looks smooth from a distance but on

close-up examination can be seen to be made from grains of sand. If so, it would need a quantum theory of space-time to be developed.

There are some indications that light from distant stellar explosions, known as gamma-ray bursts, are delayed according to their wavelength as they travel across space. This is important because space-time particles would slow down shorter wavelengths of light more than longer wavelengths.

There have been too few observations to prove or disprove the quantum nature of space-time. The puzzle remains: what is the space-time continuum?

The Large Hadron Collider is searching for dark matter candidates called neutralinos



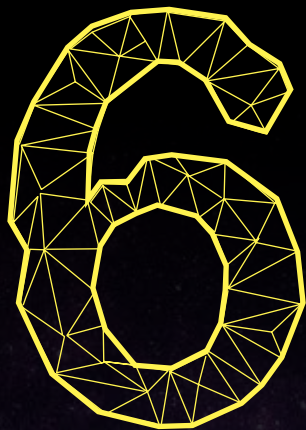
What is dark matter?

Almost every galaxy that astronomers have currently studied spins faster than they can explain. This means that there must be some other source of mass that we are unable to directly detect. Unfathomable galactic motions first came to light in the 1930s thanks to the work of Swiss astronomer Fritz Zwicky. He postulated that the extra mass must come from an unseen gas. He called this gas 'dark matter'.

By the 1970s, the need for dark matter was worse than ever. Astronomers were seeing far too much movement in the individual galaxies, yet they were convinced that the dark matter could not be atoms otherwise they would have found it already. Particle physicists provided a

possible solution because they were predicting relic particles of nature that are invisible to light but interact through gravity.

"We are now at a point where a lot of experiments on Earth stand a realistic chance of seeing something," explains Pontzen. One of those experiments is the newly upgraded Large Hadron Collider at CERN, which is now looking for neutralinos. These are currently the best candidate particles for dark matter, but are only hypothetical. If CERN does not find them, it will be back to the drawing board. ►



How did the Moon form?

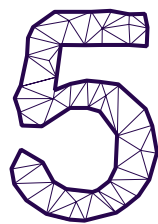
The origin of the Moon has proven remarkably tricky for astronomers to understand. In the late 1990s, planetary geologists felt that they had finally zeroed in on the answer. They called it the 'Big Splat'.

The idea involves a world about the size of Mars striking the Earth a glancing blow so that the shattered world gathered in Earth's orbit. Once there, the debris coalesced to form the Moon. Moon rocks brought back by the Apollo astronauts corroborated this scenario. But then it all went wrong.

Better measurements showed that the Moon's rocks were not just similar to Earth's rocks – they were virtually identical. This would not be the case if the Moon had mostly formed out of the impactor.

"The giant impact is still the best hypothesis because all the other scenarios just seem impossible," explains planetary scientist Prof David Rothery from the Open University. Currently, researchers are wondering whether a scenario can be envisaged in which the impacting body is smaller and embeds itself in Earth, blasting out rocks to form the Moon.

The Moon could have formed from debris created in an early collision



Do we understand gravity?

Many scientists are convinced we need a new theory to explain the strongest gravitational fields in the Universe. But a much smaller group thinks that a new theory of gravity is also needed to explain very weak gravitational fields. The idea is called Modified Newtonian Dynamics (MOND). It was developed in the 1980s by the Israeli physicist Mordehai Milgrom. He made a small mathematical modification to Newton's Universal Law of Gravitation and showed that it could reproduce the rotation of galaxies without the need for dark matter. Yet no-one

knows why such a modification should exist.

ESA's LISA-Pathfinder mission could help. The craft is designed to test sensitive instrumentation in the study of gravity in space. It's set to launch this autumn, and once the payload has been shown to work, the craft could be sent on a journey to test MOND in a region between Earth and the Sun. LISA-Pathfinder is sensitive enough to show if the weak gravity there is following Newton's or Milgrom's prediction. If Newton rules, there must be dark matter. If Milgrom gets it right, he's looking at a Nobel Prize.



Mordehai Milgrom:
Nobel Prize glory?

4 What makes a planet habitable?

Before we can go looking for habitable planets in the Universe, we first have to know what makes a planet capable of supporting life. This is no easy task. There are a number of factors that determine whether a planet can support life.

Astronomers often talk about the habitable zone: the region around a star in which a planet can be warm enough for liquid water to exist on its surface. However, as Europa proves (see 'Is there life on Europa?', p42), this might be too simplistic. "I no longer think about a habitable zone," says Dr Peter Grindrod, a planetary scientist at Birkbeck, University of London. "Instead, I

think planetary zones can be much more localised."

What seems clear is that there needs to be an energy source and nutrients, then water or some other solvent in which the biochemistry can take place. In terms of 'life as we know it', this means we should look anywhere there is abundant water and sunlight. But there could be other possible biochemistries as well. A key investigation for theoretical astrobiology is to identify other routes to life as well. Such research has the potential to drastically change the way we think about planetary habitability.

Kepler-22b:
snorkel required



3

What are black holes?

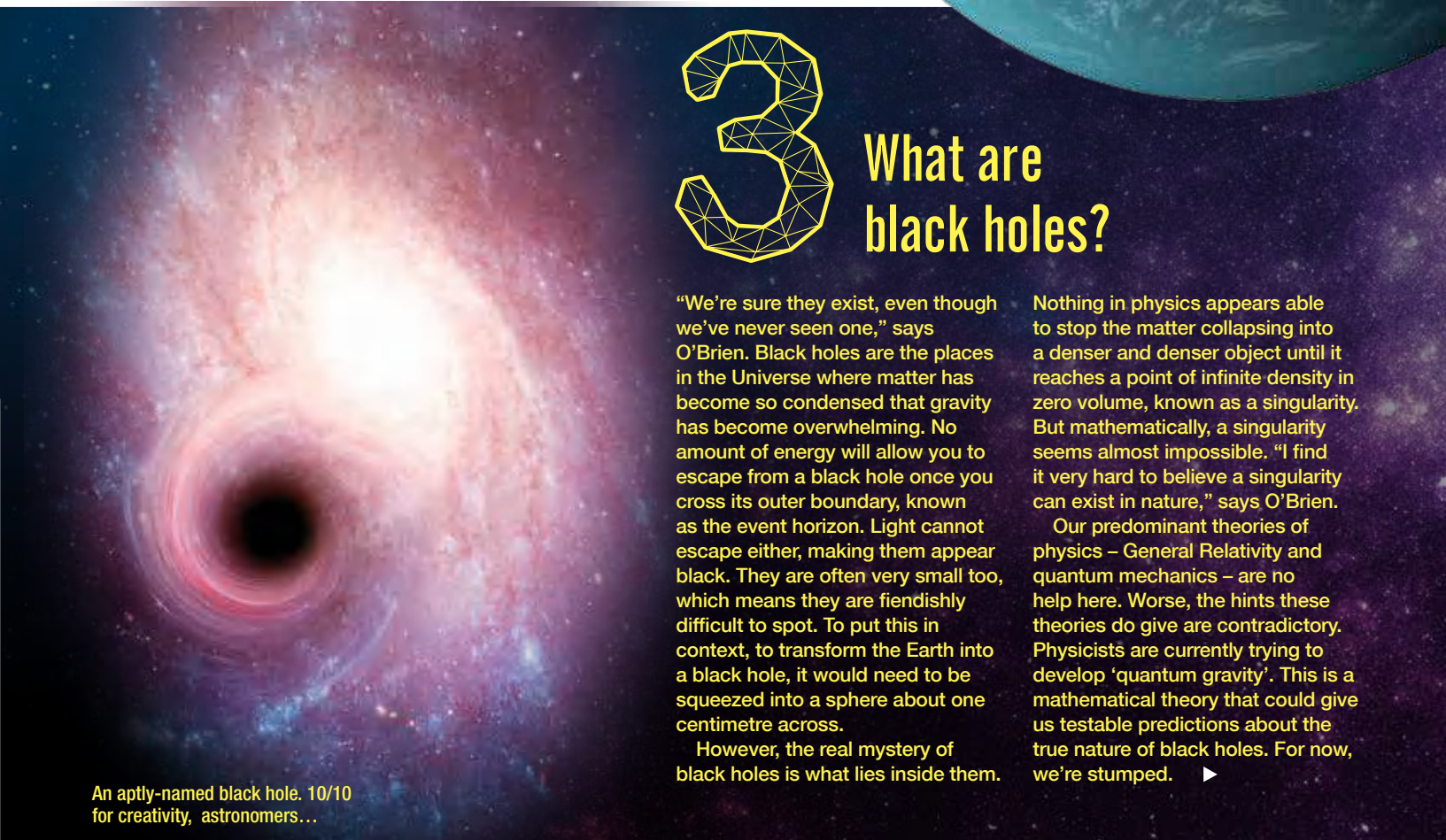
"We're sure they exist, even though we've never seen one," says O'Brien. Black holes are the places in the Universe where matter has become so condensed that gravity has become overwhelming. No amount of energy will allow you to escape from a black hole once you cross its outer boundary, known as the event horizon. Light cannot escape either, making them appear black. They are often very small too, which means they are fiendishly difficult to spot. To put this in context, to transform the Earth into a black hole, it would need to be squeezed into a sphere about one centimetre across.

However, the real mystery of black holes is what lies inside them.

Nothing in physics appears able to stop the matter collapsing into a denser and denser object until it reaches a point of infinite density in zero volume, known as a singularity. But mathematically, a singularity seems almost impossible. "I find it very hard to believe a singularity can exist in nature," says O'Brien.

Our predominant theories of physics – General Relativity and quantum mechanics – are no help here. Worse, the hints these theories do give are contradictory. Physicists are currently trying to develop 'quantum gravity'. This is a mathematical theory that could give us testable predictions about the true nature of black holes. For now, we're stumped. ►

An aptly-named black hole. 10/10 for creativity, astronomers...





Is there life on Europa?



Graphic derived from space probes showing Europa's water vapour

Europa is one of the four moons of Jupiter spotted by Galileo in 1610. At the time, the discovery caused a sensation, with some wondering why such a world had been placed into the heavens. Yet it wasn't until space probes took close-up observations in the 1970s that Europa's true mystery came to light.

Its neighbouring moon, Io, suffers from giant eruptions that throw sulphurous lava high into space. This volcanic activity is sustained by a gravitational tug-of-war that sees Jupiter pulling the moon one way, and the other moons pulling it the other. On Europa, these forces are not so severe. They cannot spark volcanism, but they can keep the moon's interior warm enough to melt much of the ice. Europa's ocean is so large that it must contain two to three times more water than all the oceans on Earth put together.

On Earth, one theory states that life started on the dark ocean floor around

hydrothermal vents called black smokers. Black smokers occur when water heated in the interior of our planet jets up into the ocean. The water carries dissolved chemicals that provide nutrients for the ecosystem's exotic microorganisms. Could the same be happening on Europa? Prof David Rothery, a planetary scientist at the Open University, thinks it's a distinct possibility. He says: "Europa is one of the most promising places to look for life. It has everything you need."

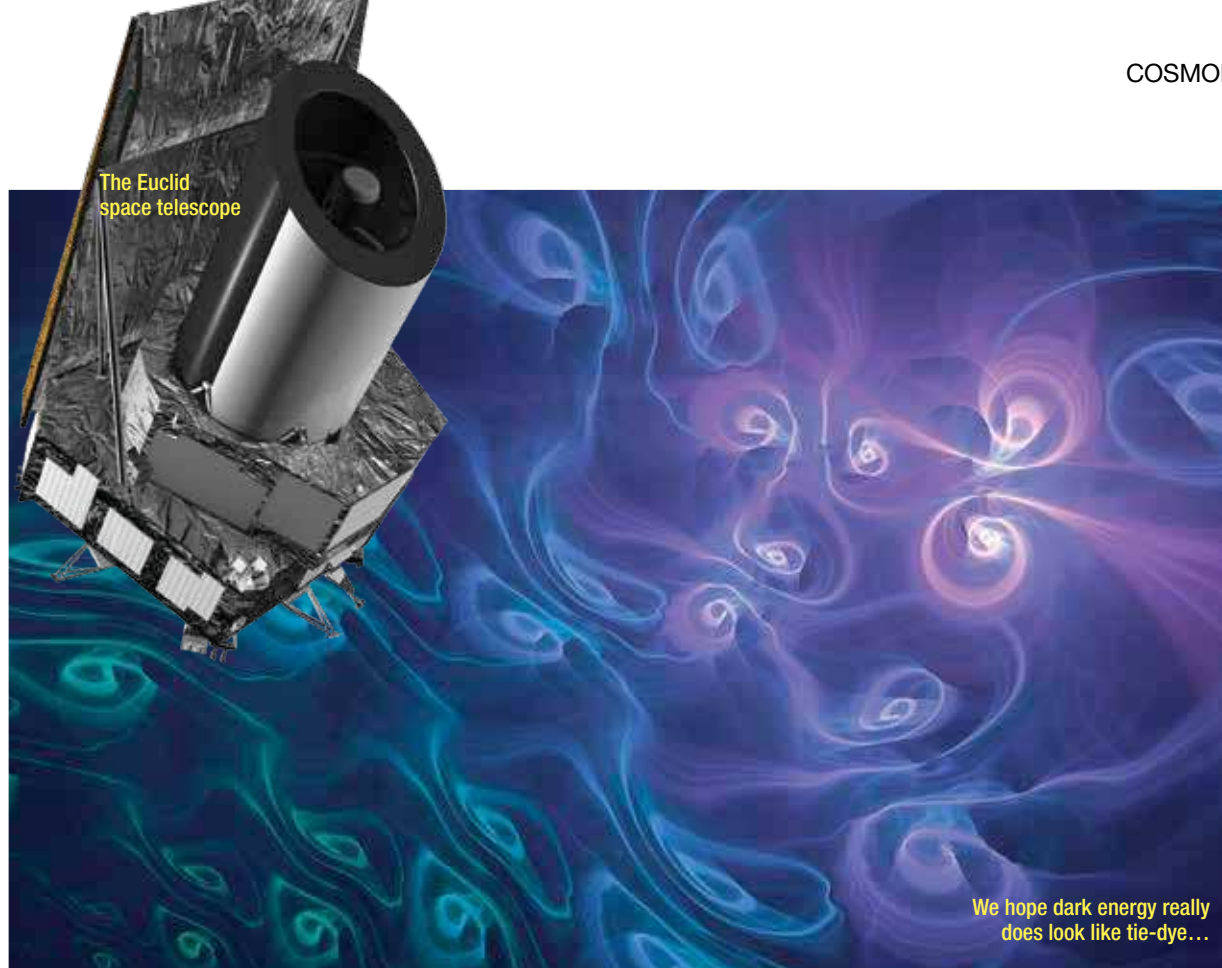
NASA's Europa Clipper mission will determine whether Europa possesses the right conditions for life. There is no precise launch date, but NASA expects it to be on its way in the 2020s. In 2016, \$30m (£19m approx) will be spent developing the craft and its instruments.

In 2012, the Hubble Space Telescope spotted water vapour

around the moon's south pole, implying that the ice is thin or fissured, allowing the subsurface water to escape. Planetary geologists have seen cracks appearing on Europa because of the gravitational forces that are at work. All this means that Europa Clipper could directly sample the water by flying through these plumes. Maybe it could look for the evidence of life?

"Once you are at Europa, it is easier to look for life than at Mars," says Rothery. This is because any microbes that have formed in the ocean could find themselves transported to the bottom of the ice crust on the rising currents, and then jetted through the cracks, bringing them to the surface where they could be studied.

Assuming that the signs remain positive for life, a follow-on mission could be designed to land on the icy surface and burrow down into the ocean below.



1 What is dark energy?

When it comes to a list of cosmic unknowns, there is no question about what tops the list. "Dark energy is certainly the biggest mystery in our understanding of the present day Universe," says Pontzen.

In 1929, US astronomer Edwin Hubble established that distant galaxies are moving away from us. Belgian astronomer Georges Lemaître had predicted this behaviour in 1927, when he calculated the expected rate of this expansion. Rather unjustly, this is now called the Hubble Constant.

By the 1990s, the Hubble Space Telescope was in orbit and was being

used with ground-based telescopes to measure the rate at which this expansion changed across the breadth of the observable Universe. Two international research teams were racing to make this measurement as it would reveal the fate of the Universe: whether it would expand forever or fall back together, coming to an end in a catastrophic 'Big Crunch'.


It seemed obvious that the expansion must be decelerating, because the gravity generated by the matter in the Universe would resist the expansion. What the teams discovered was the complete opposite – the expansion is getting faster. Further research has shown that the acceleration began about seven billion years ago, when the Universe was about half its current age.

It is as if some previously undetected anti-gravity substance is dominating the behaviour of the Universe. It makes up about 70 per cent of all the matter and energy in the cosmos, and is called 'dark energy'. Yet uncovering its identity remains very difficult. "Frankly, we are still pretty clueless," says Pontzen.

There are two leading possibilities: it

is either an energy, or a force of nature. If it is an energy, then it will have to display properties unlike any other energy. Some people call it negative energy, because instead of generating gravity, it creates a kind of anti-gravity. If it is a force, often termed 'quintessence', then it is very weak. But over the vastness of space, it builds up into the acceleration we see around us.

To try to discriminate between these two options, the European Space Agency is building a space telescope called Euclid. Launching in 2020, it will map galaxies to a distance of 10 billion light-years, to reveal the way dark energy has moved them around. It will allow cosmologists to describe the behaviour of dark energy, such as whether it changes from place to place.


Whatever dark energy turns out to be, it will require a re-write of the textbooks when we finally understand its true nature. 

Stuart Clark holds a PhD in astrophysics and is author of *The Unknown Universe* – out September 2015.

HIROSHIMA: RISING FROM THE ASHES

Seventy years ago, Hiroshima was decimated by the Little Boy atomic bomb. **Mun Keat Looi** charts the city's unexpected recovery in the weeks and months following the blast





“Looking up, the orange colour of the Sun, along with the sound of the plane overhead. As I covered my head a huge bang came and the entire barracks was blown away, many people losing consciousness as a result. From behind a windowsill, the hell that was the reality in front of me was being taken in by my eyes, accompanied with the groans of its victims”

Hiroshima survivor

Hiroshima, Japan, Monday 6 August 1945. At 8.15am, the US bomber Enola Gay dropped ‘Little Boy’, the first nuclear weapon ever used in warfare. Measuring just 300cm in length and 70cm in diameter, the atomic bomb was the pinnacle of the Allies’ \$2m Manhattan Project. It was a marvel of scientific engineering, and an awesome show of military might delivering unprecedented destruction. Just three days later, Fat Man exploded over the city of Nagasaki. These remain the only two instances of nuclear bomb use in a warfare situation.

Little Boy detonated just 43 seconds after its release, and the 4,400kg payload unleashed a punch equivalent to 15 kilotonnes of TNT. Little Boy missed its target, which was the T-shaped Aioi Bridge traversing the city’s Ota and Motoyasu rivers, because the wind carried it around 250m away. There, it detonated 600m above ground, reportedly over a surgical clinic.

The explosive trigger set off the real mechanism. The bomb contained radioactive uranium-235, which was pushed into a spiral of decay. Each atom broke down to release neutrons, gamma rays and a huge amount of energy. ►

These parts in turn destabilised neighbouring uranium atoms, in a nuclear fission chain reaction that used up 10 per cent of Little Boy's 64kg of uranium stock.

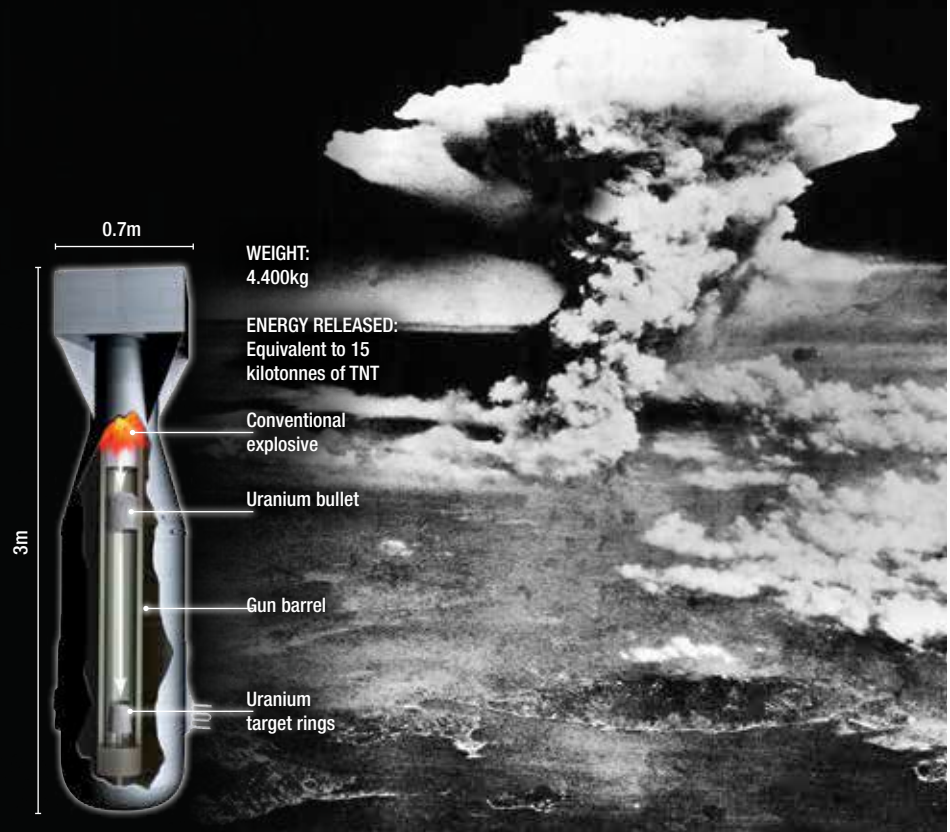
Within one second, a fireball 280m in diameter burst forth with a core temperature of over 1,000,000°C. Its heat rays raised surface temperatures to between 3,000°C and 4,000°C (iron melts at 1,500°C), scorching anything exposed to it. Birds burst into flames mid-flight. Paper as far as 2km away ignited. Entire houses were set alight, and structures collapsed in fires that would rage for another six or seven hours.

Heat blast

The extreme temperature rise suddenly expanded the air around it, generating a tremendous blast travelling faster than sound. Just 500m from the centre of the blast, the atmospheric pressure reached 19 tonnes per square metre. Anyone not already incinerated was blasted by the splintered glass of exploding buildings – survivors alive today still have fragments embedded in their bodies. Then, a reverse. The sudden drop from high to low air pressure in the space behind the blast caused a tremendous backdraft, popping the eyeballs and internal organs of anyone unfortunate enough to be caught in it.

THE ATOMIC BOMB 'LITTLE BOY'

An aerial photo of Hiroshima, shortly after Little Boy was dropped



BLAST RADIUS OF HIROSHIMA



Effect of a 15 kilotonne atomic bomb

Fireball: The Little Boy bomb was detonated 600m above the city. A fireball measuring 280m in diameter exploded forth, raising surface temperatures up to 4,000°C

All buildings collapse: Even heavily built concrete buildings are severely damaged or demolished; fatalities approach 100 per cent.

High levels of radiation: Those closest to the bomb received the highest doses of radiation.

Residential buildings collapse: The atom bomb destroyed 76,000 houses, many of which were built from wood. Around 90 per cent of the city's buildings were within 3km of the impact zone.

Thermal radiation: Around 50 to 60 per cent of people within 2km of the hypocentre suffered from excessive scar tissue because of burns to the skin. While burns were worse in the victims that were closest to the bomb, even 2km away the temperature was still sufficient to cause paper to ignite.

Hiroshima as it happened



Bomb dropped

At 8.15am, Enola Gay drops Little Boy on Hiroshima. A total of 10 per cent of its 64kg of uranium-235 undergoes nuclear fission.

6 August 1945

Fireball

The Little Boy nuclear bomb emits a 280m fireball across the city, increasing the surface temperatures up to a scorching 4,000°C.

1 second later

Expansion

The sudden rise in temperature expands the air. Atmospheric pressure reaches 19 tonnes per square metre. Almost every structure collapses.

Pressure plunge

Air pressure near the hypocentre plummets from high to low. This causes air blowing out from the hypocentre to reverse, sweeping winds towards the centre with tremendous force.

Poison rain

Black rain falls, showering the west of the city in dark droplets of mud, dust, soot and radiation from the mushroom cloud.

30 minutes later

Nearly everyone within a kilometre of the detonation centre (the ‘hypocentre’) died.

In fact, it could have been worse. Had Little Boy delivered its payload into the ground and not exploded in mid-air, its toll to the population and environment could arguably have been higher. As it was, it was still devastating. As the fireball rose, the ascending air currents surged into the stratosphere, carrying the remaining 90 per cent of Little Boy’s radioactive material – which hadn’t undergone nuclear fission – with it. Those who came near the hypocentre for rescue and relief or to search for their families absorbed radiation and fell ill.

Much of the radiation took the form of gamma rays, but the major damage came from the 10 per cent that was made up of neutrons. These had the potential to cause more damage to body cells.

Half an hour after the explosion, black rain fell. The iconic mushroom-shaped cloud of the explosion drifted northwest, showering western Hiroshima in dark droplets of mud, dust, soot and radiation. Dead fish floated to the surface in ponds and rivers where the rain fell. Yet the survivors, burnt, parched and desperate, drank the rain.

Atomic aftermath

People started vomiting several hours later. After a few days, the first symptoms of radiation sickness were evident: fever, fatigue, bleeding in the gums and under the skin. It was all cell damage caused by radiation. Hair thinned and eventually just broke off. Diarrhoea, which for some lasted as long as three months, came from damaged cells lining the intestines. Those on the receiving end of the highest doses died within 10 to 20 days. The radiation also killed stem cells in the bone marrow so people couldn’t make blood platelets, white blood cells or other key parts of the immune system. They bled out and

“About three seconds after a blinding flash of light, a thunderous roar came down from the other side of the mountain. A big mushroom cloud could be seen growing, glinting brilliant silver under the Sun”

Hiroshima survivor

couldn’t fight infections. Many died within two months.

The closer a person had been to the hypocentre, the higher the radiation dose they’d received. The average dose for people within 2.4km of the bomb was 200mSv (millisieverts) – 100 times the level most people are exposed to in a year. Those closest to the bomb received 500mSv or more. Deaths from radiation sickness continued to rise for the next month, and didn’t decline for another month after that – though it was hard to tell whether a death was from radiation, injuries or burns.

The survivors of Hiroshima were scarred mentally and physically. Around 50 to 60 per cent of those within 2km of the hypocentre suffered excessive scar tissue. Cataracts were common. Studies have found “statistically significant



A destroyed Hiroshima photographed in April 1946

Illness

The first symptoms of radiation sickness appear, such as fever, fatigue, bleeding in the gums, hair loss and diarrhoea.

6-8 August 1945

Switch on

Power in some areas of the city is restored. A limited rail service resumes on 8 August.

7 August 1945

WWII ends

Fat Man, the second atomic bomb, is dropped on Nagasaki, ending WWII.

9 August 1945

Hope blooms

Canna flowers miraculously emerge in the Hiroshima rubble, giving residents hope.

September 1945

Fresh start

Typhoons hit the Hiroshima region, bringing in new soil and sand.

October 1945

Nature wins

Hiroshima's cherry trees bloom once again, less than one year after the bomb hit the city.

Spring 1946

"With their skin turned red, everyone seemed to walk like ghosts, with both hands reached out in front of them. Their skin, like the skin of potatoes, would stop at their nails and start to dangle from there"

Hiroshima survivor



A mother and her child sit in the rubble of Hiroshima in December 1945

excess risks" in survivors for chronic hepatitis, liver damage, thyroid disease and cardiovascular disease. For those in the womb when the bomb hit, the effect on mental disability rose with increased radiation dose, along with impaired growth and development. If the physical pain didn't hurt survivors enough, they also suffered stigma. They were shunned and sometimes persecuted by their peers, who were fearful of their possible disease and radioactivity.

There was more to come. "For those who survived the immediate effects of the atomic bombs, the most important long-term effect is an increased risk of cancer in those who were exposed to ionising radiation," says Prof Sarah Darby at the University of Oxford. Initial suspicions were that the radiation would cause genetic damage to sperm and eggs. But there has been no evidence of abnormal effects in children conceived by survivors after the bombing.

The survivors were not so lucky. An increase in cancer diagnoses was first noted in 1956 and grew throughout the



1960s. By 2000, around 1,900 survivors were thought to have died from cancer linked to radiation. Thyroid and breast cancers were the most common, along with stomach and lung. Arguably the worst was leukaemia. The signs of this blood cancer began appearing in children two to three years after the bomb.

Studies conducted by the Hiroshima-based Radiation Effects Research Foundation (RERF) have concluded that between 1950 and 2000, 46 per cent of

leukaemia and 11 per cent of other cancer deaths among survivors were due to radiation from the bombs. "These studies confirm, beyond any reasonable doubt, that an increased risk of cancer can occur without causing [obvious] tissue damage," says Darby.

"The effect of radioactive black rain was definite and far-reaching," says Dr Aya Homei, a science historian at the University of Manchester. "The question of how far black rain reached has been a point of

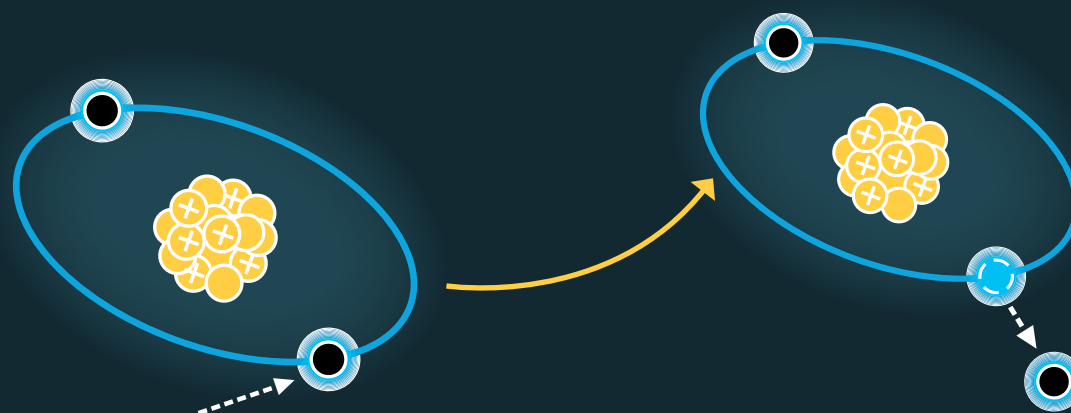
political contention in Japan, given that the answer to this has affected whether or not a survivor would be entitled to a government subsidy for their healthcare or not."

Recovery

Two days after the bombing, Manhattan Project physician Dr Harold Jacobsen was quoted saying that nothing would grow in Hiroshima for 70 years. The earth was scorched and melted. Around 90 per

RADIATION AND DNA

How the bomb affected its victims' genes

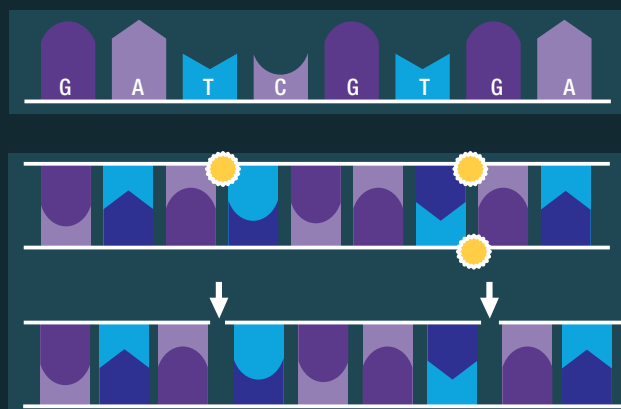


1. RADIATION WAVES

Gamma and neutron waves, like those emitted in the explosion of Little Boy, are types of 'ionising radiation'. This means that they have enough energy to knock electrons from atoms to create ions.

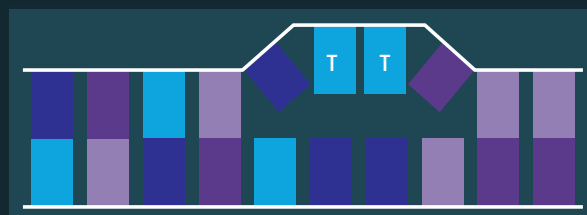
2. DNA DAMAGE

DNA contains four bases - cytosine, guanine, thymine and adenine. The ionised particles can cause breaks in the structure of DNA. Cells can repair some of these breaks, but they risk making mistakes during the repair. Breaks can occur across one or both strands. Cells find it much harder to fix breaks across double strands.



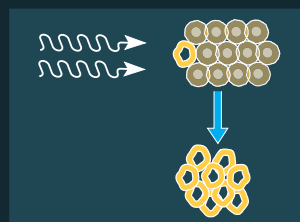
3. CODE BREAKER

It is also possible for radiation to alter the genetic code directly. Gamma and neutron radiation can change one of DNA's bases into another, or can even make two bases stick together.



4. CANCER CREATOR

The mistakes made by the broken DNA are called mutations. Sometimes, the mutations can be so bad that a cell no longer understands its instructions. Rather than repairing itself or self-destructing, it may multiply, which can lead to a tumour.



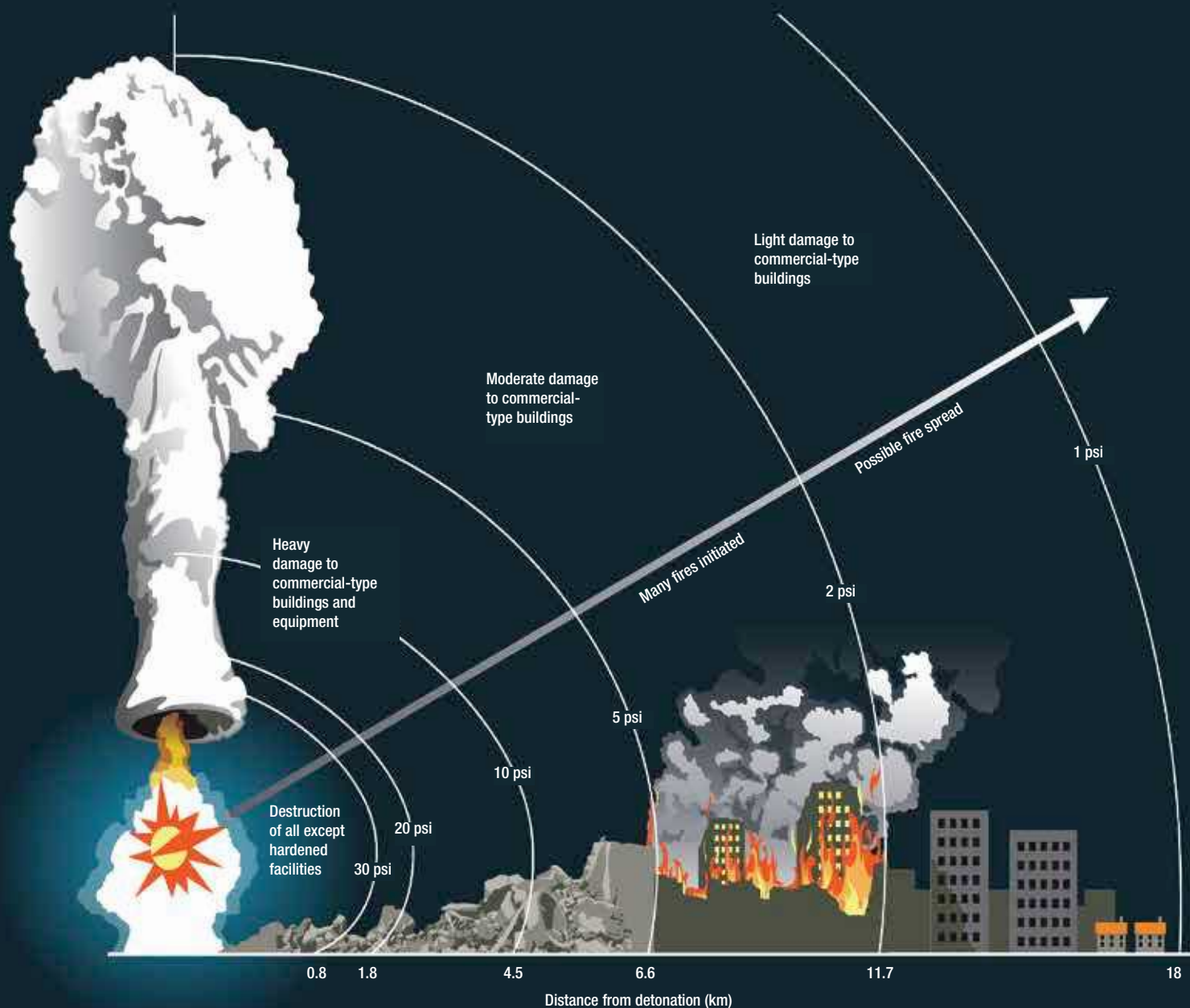
A MODERN BOMB...

Today's weapons are capable of wreaking even more destruction than Little Boy

The bomb dropped over Hiroshima unleashed a punch equivalent to 15 kilotonnes of TNT. This was sufficient to destroy the city and claim thousands of lives. Today, technology has moved on and more destructive weapons have been developed. The most powerful nuclear weapon ever detonated was the Tsar Bomba, with a yield equivalent to 50 megatonnes of TNT. It was tested over the Arctic Sea

in October 1961. While many nuclear weapons have now been dismantled, a number of countries still possess them, including the USA, France, the UK, Russia, North Korea, Pakistan, Israel, China and India. Precise numbers of nukes are top secret. Below is a scenario in which a one megatonne bomb – up to 75 times the yield of Little Boy and roughly equivalent to the USA's B83 weapon – is detonated at a height of 2.2km.

One of the Royal Navy's Trident-class nuclear submarines



After effects

The US establishes the Atomic Bomb Casualty Commission to study effects of radiation on survivors.

1947

Cancer cases

Some children who were exposed to radiation from the bombs start developing signs of leukaemia.

1947 -48

Peaceful city

Hiroshima is designated a City for Peace by mayor Shinzo Hamai. This is a key event in the city's recovery.

1949

US exit

Japan becomes independent after US forces leave the country.

1952

Health scare

An increase in cancer diagnoses among survivors is noted, growing in number throughout the 1960s.

1956

Time bomb

Around 1,900 survivors are estimated to have died from cancer caused by the bomb.

2000



Canna flowers sprouted just one month after the bomb

cent of the city's buildings had been within 3km of the impact zone. The explosion wiped out 76,000 houses, along with some 80,000 people. Any flora or fauna in the area were incinerated.

Around a month after the bombing, just 800m from the centre of the explosion, red canna flowers sprouted in rubble of Hiroshima's wasteland. This seemingly miraculous event gave hope and courage to the survivors. Yet this isn't actually that surprising, says Prof Jim Smith at the University of Portsmouth.

It would take "an awful lot" of radioactivity to stop plants from growing, he says. In fact, it would require hundreds of times more than the levels at Hiroshima, which were relatively low when compared to a nuclear accident like the Chernobyl power plant, where flora and fauna have similarly recovered. "It would surprise me if there was a problem with any plant recolonising," he says. "The impact of the actual bomb itself would be much more environmentally damaging than the subsequent radiation."

On the night of 17 September 1945, the Makurazaki typhoon hit Hiroshima. It killed over 2,000 people and flooded large areas of the city. This natural disaster brought in new, radiation-free topsoil and sand from outside the region.

By spring 1946, Hiroshima's cherry trees

"Tests have shown that the radiation in an area exposed to the force of an atomic bomb will not be dissipated for approximately 70 years. Hiroshima will be a devastated area, not unlike our conception of the Moon, for nearly three-quarters of a century"

Dr Harold Jacobsen

were revived. By the summer, oleander flowers – known for their resilience and now the official flower of Hiroshima – were in bloom. As the city revived through further years of slow rebuilding, fruit and vegetables such as tomatoes and cucumbers were grown among the shacks multiplying in the city's midst. Crucially, 81 of the city's bridges survived, aiding recovery efforts. By the mid-1950s, Hiroshima's population had returned to its pre-war level.

Seven decades after the atomic bomb, Hiroshima is green once again. Many of its trees are gifts from donors from across Japan and overseas. Yet 170 trees are themselves survivors of the blast. These are known as 'hibaku jumoku' and consist of 32 different species. Just 370m from the blast centre stands a defiant weeping willow. Just like Hiroshima's human victims, the 'hibakusha', they live on. 🍅

Mun Keat Looi is an award-winning science writer and editor.



Today, Hiroshima is a thriving industrial city with a population of 1.1 million

GETTY, PRESS ASSOCIATION, ISTOCK ILLUSTRATOR: PAUL WESTON

PORTFOLIO



Leopard

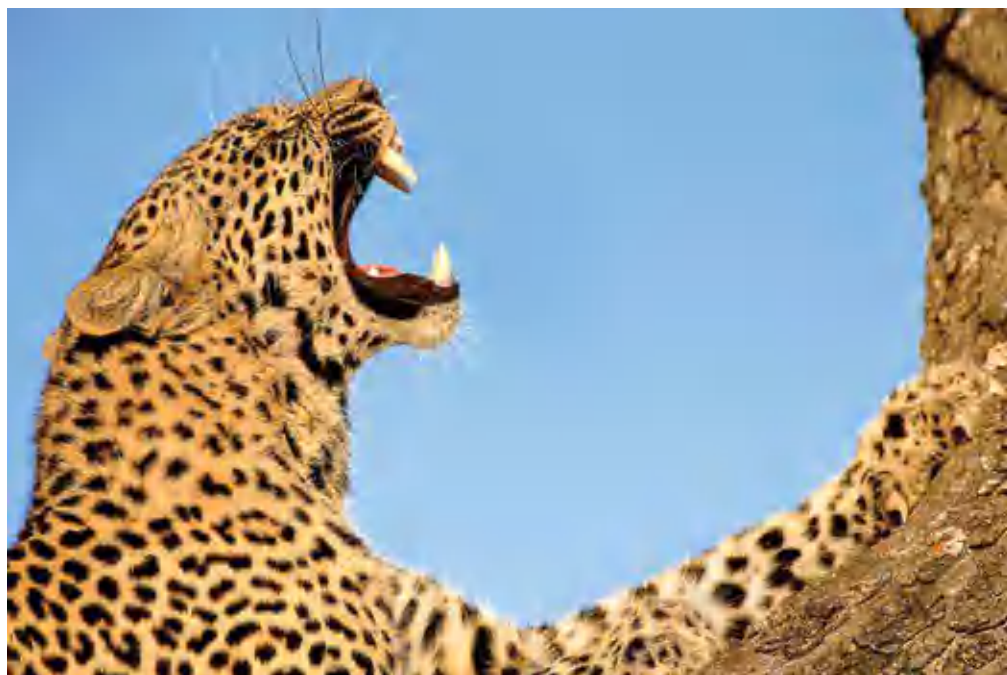
It is said that a person does not see a leopard – a leopard allows itself to be seen. Having spent three years tracking wild leopards in South Africa, I can attest to the truth of this epigram. But I believe that the leopard's very elusiveness may contribute to threats to its future – if an animal is not seen, then it cannot be appreciated, and an animal that is not appreciated will not be conserved. My aim, then, was simple: to present the naturally shy African leopard to be appreciated in its preferred environment – the black of the African night by **Greg du Toit**

Darkness is the leopard's environment, its cloak and its weapon: in most areas, Africa's smallest big cat stalks after sunset. I hoped to capture the essence of the relationship between night and nocturnal hunter, the leopard's stealth and ability to melt instantly into the blackness. So for this image, taken in Sabi Sand Game Reserve abutting Kruger's western boundary, I chose to surround the leopardess with darkness, using the kind of low-light photography that has only recently become possible thanks to advances in digital cameras. I spent many months in the field adjusting my technique and waiting for the right moment to capture this frame, lit only by a weak torch shone from one side, before the leopard vanished into the impenetrable bush.



Leopards spring up trees with effortless grace, to escape other predators – lions and hyenas, in particular – and to store prey. In fact, they are the only large predators of Africa's savannah to do so, and I was determined to capture an image of this characteristic behaviour. This shot – snatched as a female descended an acacia in Kruger as the sun's last rays faded – proved to be the toughest of the project. Panning vertically allows much less time to synchronise the camera's movement with that of the animal. Miraculously, after taking this photo I was able to follow her, and watched as she caught a scrub hare – one of the few kills I witnessed during the project.

Leopards seem to enjoy lounging in trees. From these elevated viewpoints they are able to spot both potential prey and danger, evade flies or simply take a nap. I often spotted leopards on perches that seemed – to my eyes, at least – absurdly uncomfortable. But this female had found a large, welcoming fork in a marula tree in Sabi Sand Game Reserve, and promptly fell asleep – to my frustration: the warm, early morning light was fast disappearing. Just when I was about to pack up and leave, she awoke, raised her head and, with an almighty yawn and stretch, extended her claws, adding a delightful extra element to my frame.



Leopards carve through the bush like a hot knife through butter. This female padded past me in Greater Kruger National Park.



Mothers move their cubs between dens – a cave or thicket – every few days to avoid detection by other predators; trying to keep track of them is like playing hide and seek with a ghost. One delightful afternoon, though, this leopard emerged into a near-dry riverbed with her two cubs, a male and a female, for a grooming session before shepherding them to a new den upstream. And so, for the first time in over 14 years of trying, I photographed a leopard cub at close range.





▲ Spending so much time with leopards – 640 hours, to be exact – I learned to appreciate their unique personalities, each individual identifiable by its whisker pattern and the series of spots running across its chest. I christened this young pink-nosed female ‘Shadow’ because of her shy, elusive behaviour after leaving her mother. But though she was still short of two years old, by the time I took this photo in Kruger she had grown into a regal leopardess, lounging with confident poise atop her termite-mound throne.

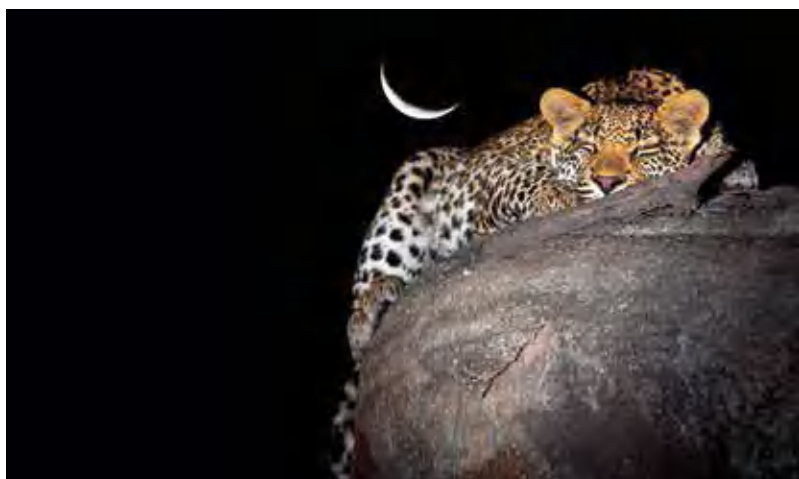


▲ Like most cats, leopards spend a lot of time sleeping – which was how I found many of my subjects. I never used bait or radio-collars; instead, by identifying an individual's territory, I could follow its tracks to where it dozed. This female in Sabi Sand was taking a break from hunting to provide for her two cubs; her large, soft footpads allow her to tread silently when stalking prey.



I found this leopardess just moments after she had caught and killed a small duiker in Sabi Sand. I watched in awe as she dragged the carcass through the bush, weary from the hunt but aware that she must quickly find a suitable tree in which to cache her prey. The sun had set and hyenas were on the prowl: she needed to hoist her prize aloft before she lost it. The orange spark in the leopard's eye contrasts with the cold blue reflection in the antelope's; to me, this symbolises the familiar, elemental cycle of life and death that makes Africa's ecosystems tick.

Leopards enjoy a catholic diet, the most diverse of Africa's big cats, eating prey as small as a grasshopper and as big as a baby giraffe. They are the most patient of cats, too: I've seen a hungry leopard stare at a rustling tussock of grass for hours before finally attacking. This inquisitive young female, no more than 18 months old, made a series of pounces into the thick grass of Sabi Sand, locating mice by the sound of their scampering – but she never came away with a meal.



◀ The leopard is a ruthless predator, but in my experience it is also a serene creature. Its quiet dignity is an aspect of its character that is often ignored, but one I hope I encapsulated in this photograph, showing a sleeping female in the northern sector of Sabi Sand.

PHOTOS BY

Greg du Toit is a wildlife photographer and eighth-generation African who has lived and worked in some of the continent's largest and wildest ecosystems. www.gregdutoit.com

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THE TROUBLE WITH TIME TRAVEL...

The cult 1980s film *Back To The Future* celebrates its 30th anniversary this year. **John Gribbin** takes a look at the mind-warping paradoxes the concept throws up



THE GRANDFATHER PARADOX

Time Travel paradoxes – or strictly speaking, puzzles – come in many varieties. But the classic example is the so-called Grandfather Paradox. In the traditional version of the story, a time traveller goes back in time and either accidentally or deliberately (if you are in a macabre mood) kills his own grandfather, before the time traveller's father has been conceived. So the time traveller is never born, so he never goes back in time, so his grandad never dies, so the time traveller is born. And so on.

A variation on this theme is used as a key plot device in *Back To The Future*. If Marty McFly accidentally prevents his own parents falling in love

and marrying, he will not exist. But as the science fiction writer Robert Heinlein put it, “a paradox can be paradoctored.” Marty does change the past, but in a positive way. He comes home to a different, better future than the one he left. But what happened to the ‘original’ future? One idea loved by sci-fi writers, and with some basis in scientific fact, is the ‘many worlds’ version of quantum mechanics. This states that all possible realities exist in some sense side by side. Think of the many worlds like the branches of a tree, each with its own version of history. If you went back in time, into the trunk of the tree, and then forward again, you might go ‘back’ up a different branch from the one you came down. You go back in time and stop your parents meeting, then forward in time up the branch in which they never met and you were never born. That’s okay, just as if you were born in London then moved to New

York, the fact that you were not born in New York doesn’t mean you don’t exist. There would, though, be one timeline in which the traveller had vanished, never to return (as in HG Wells’s original time travel story, *The Time Machine*) and another with a person who has no parents. Complicated, but not paradoxical.

Marty's parents securing his future





THE BOOTSTRAP PARADOX

Robert Heinlein presented my favourite time travel paradox in all its glory in 1941, in his short story *By His Bootstraps*. The tale gave its name to the paradox and it is often used in science fiction.

In this paradox, an item or a piece of information is passed from the future to the past, becoming the same item that is passed from the past to the future. In the case of *By His Bootstraps*, the item is a notebook found by the main character, Bob Wilson in the far future. He takes it, then travels to an earlier point in the future and uses the useful translations within the book to help establish himself as a benevolent dictator. When the notebook becomes worn

and dog-eared, he copies the information into a fresh notebook and discards the original. Towards the end of the novel, he muses that there were never two notebooks – the new one is the one that was found by him when he arrived. Mindbending! One easy-to-follow example of the Bootstrap Paradox can be seen in *Back To The Future*. At the dance in 1955, Marty McFly gets on stage and sings “an oldie” where he comes from: Chuck Berry’s Johnny B. Goode. Chuck’s cousin, Marvin, is present at the dance and holds up a phone so Chuck can listen in. Inspired by the sound, Chuck later releases the song and Marty would then hear it in the future. But who wrote it?



Robert Heinlein melted our brains with his short story *By His Bootstraps*

POLCHINSKI'S PARADOX

The Grandfather Paradox and the Bootstrap Paradox seem more like science fiction than serious science. But there is one variation on the theme that is taken very seriously by scientists, and has been discussed in research papers published in respectable journals. Their interest is fired by the fact that there is nothing in General Relativity that forbids time travel. In the language of General Relativity, closed time-like curves, or CTCs, are allowed. A CTC is a path through space-time that ends up back where it started, at the same point in space and time.

The Russian physicist Igor Novikov proposed that the way to fix paradoxes would be if there was some law of nature that ensured only self-consistent time loops would be permitted. Together with US theoretical physicist Kip Thorne and other colleagues, he developed a way of picturing this to make the point.

It starts with wormholes, those

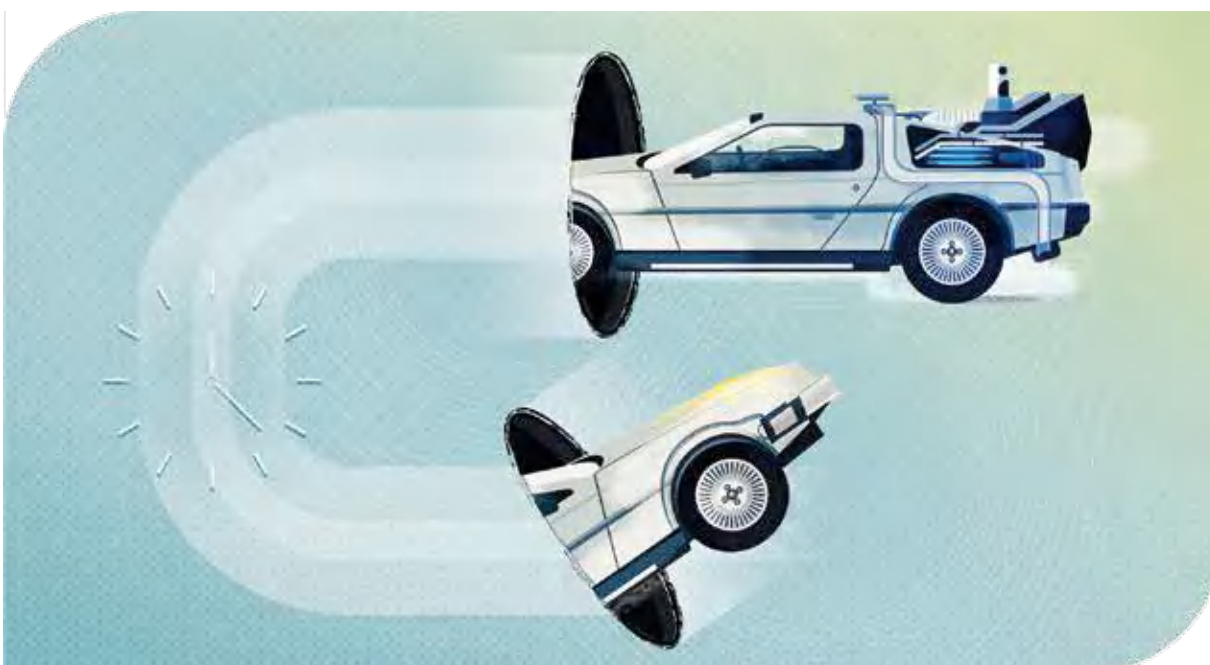
theorised tunnels through space-time that are also allowed by relativity theory.

A wormhole can be set up (in principle) with one mouth of the tunnel next to the other mouth, but with the second mouth in the past of the first mouth. Joseph Polchinski, another US theoretical physicist, pointed out how this could lead to a paradox. If a billiard ball (theoretical physicists love billiard balls) is rolled into the first mouth of the wormhole at just the right speed and angle, it will come out of the second mouth just in time to cannon into its younger self and prevent the younger self going into the tunnel. This is Polchinski's Paradox.

But this is not the whole story. There are also self-consistent CTCs. If the billiard ball is approaching the mouth of the tunnel, its older self can emerge from the second mouth and give its younger self a glancing blow exactly right to send it through the wormhole in such a way that it will emerge to give itself a glancing blow that does the same thing. There are many possible consistent trajectories of this kind. In the most extreme case, the 'second' ball emerges from the tunnel and knocks the 'first' ball completely away, but in turn it gets deflected into the wormhole, where it then takes the place of the

'first' ball. A bunch of rather hairy calculations showed that there is never a system like this where there are no self-consistent trajectories, and that in some cases there can be an infinite number of self-consistent solutions to the equations.

All of this lends weight to Novikov's conjecture, sometimes more grandly referred to as Novikov's Self-Consistency Principle. This states that time travel is allowed, but paradoxes are forbidden. This could resolve the Grandfather Paradox – if you go back and try to kill your grandfather, something will always go wrong. Take a gun to shoot him, and the bullet will misfire; poison his wine, and someone else will drink it, and so on.



BACK TO THE FUTURE: HITS AND MISSES

In *Back To The Future's* 1989 sequel, *Back To The Future Part II*, Marty and Doc travel forward in time to 2015 where they are greeted with more out-there tech than you can shake a flux capacitor at. Now that we've made it to 2015 for real, which of the cult film's predictions have actually come true?



MISS – FLYING CARS

Sci-fi writers have been predicting the arrival of flying cars for decades now, so it's no surprise the *BTTF* team gave the 2015 DeLorean a 'hover conversion'. But despite being a long-term favourite, flying cars have yet to be proven truly viable.



HIT – WEARABLE TECH

While it may so far have failed to appeal to all but the most dedicated Glass-hole, there's no denying that Google's wearable display looks eerily similar to the high-tech specs worn by the McFly family at the futuristic breakfast table.



MISS – SMART CLOTHING

For anyone caught in a downpour without an umbrella, a jacket with a built-in dryer would be a godsend. But shoes that tie themselves? Surely that's just lazy. Regardless, neither product is about to hit the shops any time soon.



HIT – VIDEO CALLS

Another perennial sci-fi staple, the video call, is now so deeply ingrained in everyday life it almost seems passé. But again, the *BTTF* guys got in on the act in 1989 with a video-calling system that's practically indistinguishable from Skype, Google Hangouts and FaceTime today.



MISS – HOVERBOARDS

The closest thing to a functioning hoverboard so far dreamed up is the Hendo. However, as it needs a special surface on which to function, it's not quite up there with the hoverboard from the movie. It's probably for the best; there are more than enough ways of ending up in the A&E department as it is.



THE TWIN PARADOX

This is the most scientifically sound and least paradoxical of all.

Special Relativity tells us that moving clocks (including biological clocks) run slow. This has been tested by experiments in accelerators like the Large Hadron Collider. Particles with a known lifetime when stationary in the lab 'live' longer when they are moving close to the speed of light.

Wormholes, although permitted by the rules, have not yet been seen, so in that sense they are hypothetical. But time dilation has been seen; it is a fact. So if one member of a pair of twins goes on a journey at a sizeable fraction of the speed of light, he or she will age more slowly than the twin who stayed at home. And when the travelling twin returns home, he or she will be younger than the twin who stayed behind.

Literally younger, in biological terms.

From the point of view of the travelling twin, time has passed

more rapidly on Earth. After a year in the spaceship, they might return to find that 100 years or more have passed on Earth. It is one-way time travel into the future, as explored in sci-fi stories such as *Planet Of The Apes*.

But hang on. Special Relativity says that all observers are equivalent, doesn't it? Why can't the travelling twin say that they are at rest, while the Earth and the other twin go on a journey into the future? All inertial observers, those in straight lines at constant speed relative to each other, are equivalent. Acceleration changes the rules of the game, and in order to get home the traveller has to decelerate and then accelerate back in the opposite direction. In the extreme example often used by paradoxers, this turnaround is instantaneous. As the cosmologist Hermann Bondi once told me, if you give each twin a paper bag full of eggs to hold, at the end of the experiment you will find the traveller covered in egg, while the stay at home twin is clean. They are not 'equivalent'.

All of this can be described accurately using equations, and the result is the same. This kind of time travel is solid science, and it works. One snag: unless you can find a handy wormhole, there is no way to get back from the future. But that is a great idea for a film title... 🍌

The LHC proved that clocks run slow



A future world in Planet Of The Apes



Cosmologist Hermann Bondi



John Gribbin is a science writer, astronomer and astrophysicist. His books include *Einstein's Masterwork* and *Timeswitch*.

THE SECRET LIVES OF WASPS



Wasps buzz their way into our lives every summer. But **Adam Hart** says that these striped insects are horribly misunderstood...

2 in

is the maximum length of the Asian giant hornet – the largest wasp in the world

LIFE CYCLE

Most of us are familiar with social wasps, and they all have similar life cycles. At the end of summer, the queen wasp mates and then overwinters in a state of torpor. In the spring, she wakes up and looks for a suitable place to start a nest. She uses wood pulp to build a small nest in which she can rear her first batch of female workers. Workers, who don't reproduce, rapidly take over the running of the colony while the queen lays eggs that will develop into more workers.

As the season progresses, the workers produce new potential queens by feeding some larvae richer food. The queen (and some workers) can also lay unfertilised eggs that develop into males. The reproductive males and females mate; the queens overwinter while the males die. As the colony winds down in early autumn, the remaining workers also die.

POPULATION

Wasp populations tend to fluctuate, and whether it is a good or bad year for wasps is the subject of much media attention. In fact, there seem to be two-year and possibly seven-year cycles that are driven by a combination of factors related to the biology of wasps and, crucially, the climate over the preceding year. For example, cold winters are good for wasps because the queens remain in the relative safety of torpor longer, emerging later in spring when there are more resources to support them.

Press reports of 'wasp invasions' typically appear in late May and June but are usually premature. Plus, a native insect having a good year is hardly an invasion!

30,000

wasps species are identified in the world

ALIEN INVASION

Mild winters could mean that colonies start surviving the colder months, continuing to grow and building massive nests. This is already a problem in New Zealand and Australia, which both suffer from introduced wasp species. Meanwhile, climate change could lead to new species reaching the UK. British beekeepers are already on the lookout for the Asian predatory wasp; this bee-killing hornet recently arrived in France from Asia.

WHICH WASP?

The most likely species you'll encounter is the common wasp (pictured right), but the median wasp, the tree wasp, the Saxon wasp, the German wasp and the red wasp can also be frequently encountered in some areas.



BBQ BLIGHTER

It is the worker wasps that we see out and about in the summer, looking for food. Common wasps feed their larvae on insects, which the workers bring to the nest. The adults consume nectar, ripe fruit and other sugary foods – including jam sandwiches and fizzy drinks.

Large mandibles allow the wasps to strip wood and rip apart their prey

90kg

was the weight of a two-year-old German wasp nest found in Tasmania in April 2015

The yellow and black colouring deters potential predators

WHY WE NEED WASPS

Wasps are predators that control plant pests and enhance biodiversity by preventing common species becoming dominant. One worker wasp can collect over 100 aphids a day, while some wasps will pollinate flowers. They are a vital part of the ecosystem. Social wasps demand our attention, and sometimes not always for the best reasons, but they also deserve our interest and our respect.

The sting is a modified ovipositor, which is an egg-laying organ that's only present in females. Unlike honeybees, wasps do not die after they sting you

Prof Adam Hart lectures in ecology and animal behaviour at the University of Gloucestershire, UK.



HISTORICAL TORTURE

BRAZEN BULL

A hollow brass structure in the shape of bull, the Brazen Bull was a torture device employed in Ancient Greece. The victim was placed inside and the door was shut sealing him in. A fire was lit underneath the belly of the structure. As the heat increased, the victim would scamper around inside screaming, trying to escape, the echoes of which would bounce off the structure's insides in the manner of a bull bellowing. This would further terrify the victim, exacerbating his predicament. He would eventually succumb to death due to the high temperature of heat generated inside.



SPANISH DONKEY

Known by other names such as the Wooden Horse, the Wooden Pony, the Spanish Donkey was amongst the most grotesque forms of torture that were used. The wooden device is triangular in shape and particularly sharp at the top. Two beams on the side, give it the shape of a horse, for support. The victim is made to sit up on the top with all the body weight focused on the groin. Weights are then tied to the victim's ankles with the singular purpose of torturing them and plus dragging their weight down to inflict and severely injure their crotch and sometimes even slicing it in half. Victims if they survived, would not be able to walk without pain.

INQUISITION CHAIR

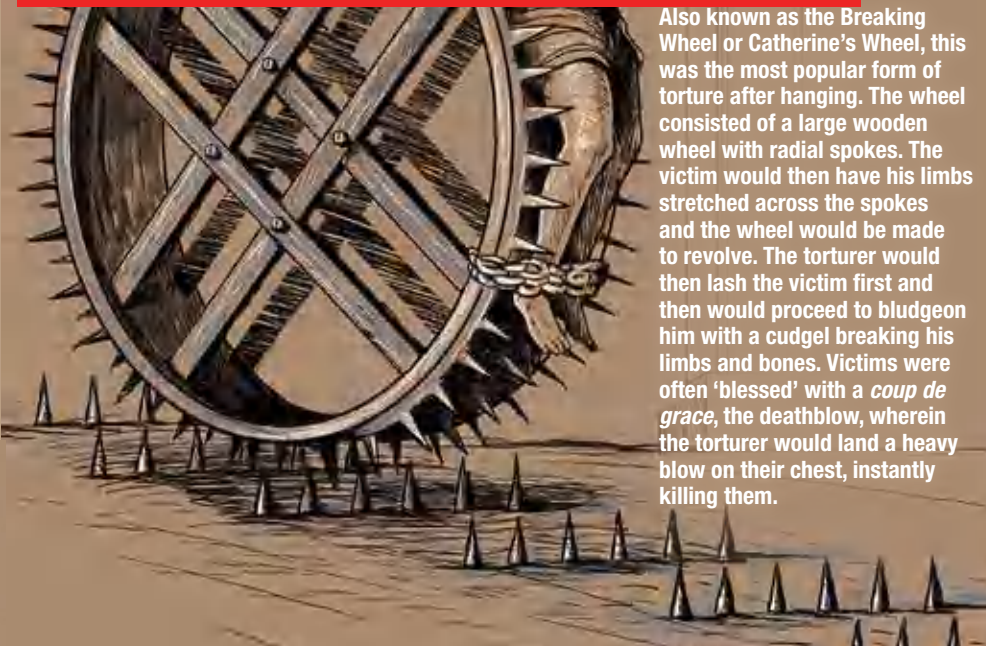
If there is one torture device that is universally associated with the Middle Ages, it is the Inquisition Chair. Also known as the Judas Chair or the simply the Torture Chair, the device was extremely succinct in its endeavour to torture the poor victim. The victim, naked again, is made to sit on a chair that is covered in spikes entirely – from the seat to the backrest, the armrest and even the chair legs! An estimation of 50 to 500 spikes ranging in length are attached to the chair. They were then restrained; the straps pushing their limbs into the spikes further. A fire is ignited at the bottom of the chair, where the flames heated the spikes allowing them to pierce and eventually cauterize the flesh off the victim, leaving them with 3" holes as a reminder of their 'crimes'. The chair was bought out to extract information from the victim.



METHODS



...ss. Vicious. Savage. Ruthless. We go on, but **Moshita Prajapati** would let you come with your adjectives. You have read the list of the Middle most torturous methods



Also known as the Breaking Wheel or Catherine's Wheel, this was the most popular form of torture after hanging. The wheel consisted of a large wooden wheel with radial spokes. The victim would then have his limbs stretched across the spokes and the wheel would be made to revolve. The torturer would then lash the victim first and then would proceed to bludgeon him with a cudgel breaking his limbs and bones. Victims were often 'blessed' with a *coup de grace*, the deathblow, wherein the torturer would land a heavy blow on their chest, instantly killing them.

THE IRON MAIDEN

They didn't torture the victims by blasting the music of the iconic heavy metal band. That is something the Americans discovered later. The Iron Maiden was infact one of the most violent and torturous devices used. Built and designed

like a sarcophagus with spikes positioned at varying levels on the inside of the doors and at the back of the structure. The double doors would be opened to let the victim in and the doors would then be shut. The spikes would then penetrate the victim's Flesh. It was not enough to ensure a quick Death. But a slow excruciating one. Victims would bleed over days, suffer from dehydration and exhaustion, and finally succumb to their death. In some cases, spikes were located at the eye level.

Ouch!



THE THUMBSCREW

Designed to inflict agony for a lifetime rather than bring upon a quick death, the Thumbscrew was an upgrade on the Pillywinks – another torture device. It consisted of three vertical metal bars, between which the victim's thumbs would be placed. A crushing bar would then slide down and restrain the thumbs to the base. The torture would begin when the handle at the top would be turned crushing the thumbs. The crushing bars were often lined with spikes to inflict further pain. This was another method of torture used on prisoners and victims to extract information.

THE LEAD SPRINKLER

Essentially a handle designed with a ladle on the end, the lead sprinkler was a handy device. The perforated top ladle part of the device could be opened up to fill it with boiling lead, water, oil or even molten metal. The contents would then be sprinkled upon the victim, inflicting scar and tissue damage. The victim in case you are wondering, was obviously restrained and sufficiently whipped before this torture method commenced.

THE RAT

If you are the squeamish kind, I suggest you skip reading about this method of torture. The unfortunate victim is made to lie supine with their limbs restrained on the floor. Then, an upturned clay bowl filled with rats (hungry ones, one assumes) is placed on their belly. Then, burning coals are placed on the base of the upturned container to generate heat. So far good? Okay. In a bid to escape from the rising heat, the rats start to escape by gnawing through the victim's flesh. This was a very effective approach to extract information from the victim.



BABUR

THE FACE BEHIND THE MOGHUL EMPIRE

How did a twelve-year-old ruler of the country of Ferghana in Central Asia become the founder of one of India's greatest empires? **Diana Preston** profiles the tumultuous rise of Babur the conqueror

Babur, the founder of the Moghul Empire, was born in 1483 in Ferghana - a remote Central Asian kingdom east of Samarkand ruled by his father. In his intimate account of his life, the *Baburnama* - the first true autobiography in Islamic Literature - Babur describes how in June 1494, as his father was hastening to a dovecote on his castle walls the parapet collapsed, precipitating him into the ravine below. 'Thus', wrote Babur, 'in the twelfth year of my age I became ruler in the country of Ferghana'.

Early years

Ferghana was one of several regions in what is now Uzbekistan and Afghanistan whose rulers - adhering to their warrior code of '*taktya takhta*', 'throne or coffin' - were in constant conflict with their close relations to claim a greater share of the fragmented legacy of two preceding dynasties - those of Ghenghis Khan and of Timur. Babur could claim

descent from both - on his mother's side from Genghis Khan and on his father's from Timur who was his great great great grandfather. A hundred years before Babur's birth, Timur, a chieftain of the nomadic Barlas Turks, had established a vast empire stretching from the borders of China to Turkey with its capital at the fabled golden city of Samarkand.

Babur was much prouder of his Timurid than of his Mongol inheritance and would have been affronted that the dynasty he would initiate in India would be known as the 'Moghuls' from a corruption of the Persian word for Mongol.

Nevertheless, it was his intelligent, able, Mongol grandmother, Esan Dawlat, who steered Babur through the dangerous early years of his rule. Babur yearned to recreate Timur's empire and under Esan Dawlat's tutelage captured Samarkand within just three years. However, his rule lasted only a hundred days. The loss of the fabled golden city was, he wrote, 'difficult for me. I could not help crying a good deal'. ►

In 1500, Babur retook the city but his second reign lasted less than a year before he was again forced to abandon it to his rivals. Having also by now lost Ferghana to his rebellious half-brother, this was the nadir of his fortunes as he wandered 'from mountain to mountain, homeless and houseless'. Then came the news that Kabul, another ancestral Timurid territory, had fallen to an outsider on the death of its previous ruler, one of Babur's uncles. Babur knew that if he could capture the city he had as strong a claim to it as anyone. He set out with only a small force but as he advanced his forces grew, the incumbent ruler fled and in June 1504 Kabul fell with little fighting. Babur recalled, 'in the end I rode there and had four or five people shot and one or two dismembered'. Once captured, Kabul would remain the then twenty-one-year-old Babur's powerbase and spiritual home for the rest of his life.

Babur knew that if he did not promise his troops fresh plunder, they might revolt. With Persian backing he made another foray to Samarkand. Though he captured the city, after eight months he was forced to abandon it forever. His thoughts now turned southward to India which both his famous ancestors had invaded.

Conquest of India

In 1221 Ghenghis Khan had reached the Indus. In 1398, the sixty-year-old Timur had captured Delhi which he looted and burned, returning home so burdened with booty it was said his army could only manage six

kilometres (four miles) a day.

Before embarking on his own conquest of India, Babur acquired cannon and matchlock muskets from the Ottoman Turks, both then unknown in northern India. After some preliminary expeditions, in autumn 1525 he launched a full-scale invasion. His timing was immaculate. The Muslim Lodi Sultanate of Delhi, which had dominated much of northern India for over 300 years, was then riven by internal feuding against the ruling Sultan Ibrahim.

Babur descended the snowy passes from Afghanistan, crossed the Indus, advanced through the Punjab foothills and reached Panipat on the hot, dusty plains only eighty kilometres (fifty miles) from Delhi before, in April 1526, he faced serious opposition – an army of 100,000 commanded by Sultan Ibrahim himself. Outnumbered by five to one, Babur exploited his only superiority – his cannons and matchlock muskets. Drawing his 700 wagons, linked together by their leather harnesses, into a defensive perimeter, Babur placed his cannons and matchlock men behind them. When the sultan's forces – led by 1,000 armoured war elephants – attacked, Babur's musket and cannon fire caused panic and confusion. Next Babur's mounted archers



An illustration depicting Babur on a rhino hunt from *Baburnama*



Babur's son and successor to the Moghul Empire, the Moghul Emperor, Humayun

attacked the disordered mass of trumpeting elephants and yelling, bewildered and frightened men from the side and rear. Within five hours 20,000 of his enemy, including Sultan Ibrahim, were dead.

Once Babur had been proclaimed ruler in Delhi by having Friday's midday sermon, the *khutba*, read in his name in the main mosque, he marched along the River Jumna to Agra. Here his son Humayun presented him with a huge diamond which he'd been given by the royal family of Gwalior in gratitude for their protection after their ruler's death fighting for Ibrahim at Panipat. It was probably the famous Koh-i-Nur, the 'mountain of light', that would reappear several times in the Moghul story.

Taking stock of his new realm, Babur was not overly impressed. 'Hindustan has few charms' he wrote, '... The cities and provinces are all unpleasant. The gardens have

"The one pleasing aspect of Hindustan is that it is large and has masses of gold and money"

no walls and most places are flat as boards. There is no beauty in its people, no graceful society, no poetic talent, no etiquette, nobility or manliness ... There are no good horses, meat, grapes, melons or other fruit ... no ice, cold water, no good food, no baths, no madrasas ... no running water in their gardens or palaces and their buildings lack harmony or symmetry'. However, he identified one satisfactory characteristic: 'The one pleasing aspect of Hindustan is that it is large and has masses of gold and money'.

Babur treated the family of his defeated enemy Sultan Ibrahim well, keeping his mother Buwa at court. However, she did not reciprocate his kindness and in December 1526 persuaded a cook to poison his food. Babur survived and had Buwa imprisoned and the cook tortured and, after he confessed, skinned alive. To cure himself Babur drank opium mixed in milk and wrote: 'Thanks be that I am alright now. I never knew how sweet a thing life

was.' In March 1527, he sufficiently recovered to defeat an alliance of Rajput rulers under Rana Sanga of Chittor at Khanua, sixty kilometres (some forty miles) west of Agra. His victory in what had been a far closer

Humayun 'do nothing against your brothers, even though they may deserve it'. He was buried in Kabul as he had asked.

Dying so soon after his invasion of India, Babur had had little time to



Babur's victory over Ibrahim Lodi, at Panipat (1526) was decisive in setting up the foundation of the Moghul Empire



An illustration from the Baburnama depicting Babur holding an audience

fought battle than Panipat left Babur undisputed master of the region.


The twilight years

However, Babur had less than four years left to live. According to some, his death resulted from the severe illness of his son Humayun. Seers suggested to Babur that if he gave away one of his valued possessions his beloved son might recover. They may have meant the Koh-i-Nur but Babur took it to mean that he should offer his own life for his son's which he did crying 'I shall sacrifice myself for him ... I can endure all his pain'. Whatever the truth of this, Humayun recovered while Babur's health deteriorated. In December 1530, aged forty-seven, he died after calling upon his supporters to recognise Humayun as his successor and urging

consolidate the Moghuls' hold on their new lands.

Under Humayun's son Akbar the empire would rise to greatness on the foundations Babur had laid. His successors would frequently turn to the *Baburnama* for insight on how to rule and never forgot their debt to their visionary forbear who had led the Moghuls into India. Ironically, though, the tradition of bloody inter-familial rivalry - '*taktya takhta*' - that Babur had also brought with him from the Central Asian steppes would taint the dynasty, hastening its disintegration over a century and a half later. □

Diana Preston is one half of 'Alex Rutherford', author of the bestselling '*Empire of the Moghul*' series of historical novels.

A close-up photograph of a Santa Cruz tortoise resting on the ground. The tortoise is facing left, with its head and front legs visible. Its shell is dark and textured. The ground is covered with dry leaves and twigs. In the background, there are trees and a clear blue sky.

A Santa Cruz tortoise *Chelonoidis porteri*, photographed in a reserve in the south-east of the island, heads for a water hole to cool off

SLOW MOTION

The Galápagos giant tortoise weighs a quarter of a tonne and travels as little as 30m a day – when it moves at all. Why would it migrate up a volcano? **Stephen blake** investigates ►



A pivotal moment in our understanding of the ecology of Galápagos giant tortoises occurred, curiously, in an Amsterdam bar.

“Did you say that you spent years radio-tracking forest elephants in the Congo?” asked Professor Martin Wikelski, chugging a beer. “But now you live on the Galápagos Islands?”

“Yes,” I replied. “My wife has just got a job there as a wildlife vet, but there isn’t much call for a professional elephant-dung counter in the middle of the Pacific.”

As it happened, Martin is director of the Max Planck Institute in Germany – and was launching a project that could use my skills. “I’m searching for a biologist with experience in large-animal ecology and radio-telemetry, and who can cope in the tropics without much support,” he told me. And so, with a handshake, the Galápagos Tortoise Movement Ecology Programme was launched.

Martin’s team researches animal migrations around the globe; rumours had reached him of seasonal journeys made by Galápagos tortoises, and he asked me to look into it. I soon discovered that, despite the iconic status of these magnificent reptiles, their ecology was still largely a mystery. Little was known about the size and distribution of the various populations scattered through the archipelago, or the ranging behaviour of individuals – including why some populations practise long-distance migration.

Tortoise trails

Over a century and a half earlier, Darwin had pondered why tortoise trails on the island of San Cristóbal, presumably etched by the shuffling of thousands of tortoise feet, ran up and down slopes. Locals told him that the reptiles moved from lowland areas up to water holes in the hills during the season between June and November known as *garúa* – when conditions are cool and dry at the coast, but misty and damp in the highlands (in Spanish, *garúa* means ‘drizzle’).

I spoke to park rangers and scientists, notably Linda Cayot and Wacho Tapia, and other local people; their observations supported Darwin’s idea of seasonal swings in distribution. “There is definitely something to this migration story,” I told Martin, “but no one has worked out the when, where, how and why. The conservation implications could be huge.” Around the world, if



Stephen attaches a GPS transmitter to Emma, a tortoise on Española Island. The tag data shows that her home range centres on the cactus visible in the background, which she uses for shade, food and moisture.

migration routes are restricted, species whose movements are curtailed usually decline precipitously. Imagine if that happened on the Galápagos.

One April day in 2009, I joined a ranger, Wilman Valle, and walked into the woods of Santa Cruz Island to fit the first of our GPS tags to a wild tortoise. My companion knew just where to find tortoises, and in a couple of hours we had glued a high-tech tag to the carapace of a young adult female we named Maria (after Wilman’s wife). A week later, 10 tagged tortoises were wandering around Santa Cruz, each collecting and storing a location data point every hour – data that would provide a unique window into the secret lives of these ancient reptiles.

Resolving wildlife mysteries is exciting, but also tinged with melancholy: with scientific discovery comes a loss of innocence. Who were we to use fancy gadgets to peer into the hidden lives of these armoured monoliths, I wondered? And would Darwin have approved?

The second question, at least, was answered emphatically by someone who should know – the naturalist’s great-great-grandson Randal Keynes, who joined me for a day spent tracking tortoises early in the project.

As we tracked a male, Sebastian, and downloaded the GPS data from his tag, we mused that this ancient creature may well have been alive when Darwin was sitting in Kent writing his masterwork. The wonder on Randal’s face as he saw the information streaming in was enough to convince me that his ancestor would have been happy with our work.

During the first few weeks of the project, we frequently downloaded data from the tagged tortoises



Giant tortoises often take lengthy baths, most likely for thermoregulation. This individual was relaxing on Santa Cruz Island



Generations of giant tortoises have followed the same well-used migration routes up to the highlands of Santa Cruz

RESOLVING WILDLIFE MYSTERIES IS EXCITING, BUT TINGED WITH MELANCHOLY: SCIENTIFIC DISCOVERY BRINGS A LOSS OF INNOCENCE

to develop our tracking skills, and mapped their movements. Then, suddenly, we 'lost' them all. There were no radio signals and no data. Panic set in. Could the tags have failed? Maybe the tortoises were just too rough with them?

One day, standing on top of the highest peak on Santa Cruz with my radio receiver, scanning the island for signs of our subjects, I heard a weak 'ping' from the tag on a tortoise called Helver. Wilman and I made a beeline in the direction of the signal and, during several hours of hard walking into the lowlands, it became stronger. Eventually we spotted Helver resting peacefully under a bush.

I had a eureka moment: we hadn't been able to find our tortoises because they had all migrated away from where they'd been tagged. Helver, who may have just completed his annual migration for the 100th time, merely stared at us, utterly unaware of the drama he'd caused.

We eventually established that – exactly as Darwin's informants on San Cristóbal had described ►

Living larders: giant tortoises made ideal ships' rations, being slow-moving as well as hardy.



EATEN TO EXTINCTION

► Like tortoises, humans arrived on the Galápagos by accident, swept there from mainland South America by strong ocean currents. As the great age of sail arrived, and the islands became a stopping point for whaling expeditions, sailors began harvesting the reptiles.

► Whalers and pirates quickly realised that giant tortoises, if flipped onto their backs, could be kept alive for many months aboard ships, providing fresh meat on long voyages.

► This trait of hardiness – which, ironically, enabled tortoise ancestors to float nearly 1,000km to the Galápagos some three million years ago – led to the extinction of several species: sailors ate almost every one. Even Darwin dined on tortoises aboard the *Beagle* – and not a single carapace was saved for science.



Giant tortoises slumber together in a sandy clearing on the rim of the Alcedo crater. The combination of soft, sandy soil and shade makes a comfy bed

– migrating tortoises on Santa Cruz usually spend the *garúa* season in the highlands, where they munch grass in tiny ranges measuring just a few hectares. With the arrival of the wet season in December they move downhill into the lowlands, sometimes following well-worn migration trails and sometimes bushwhacking their way through dense vegetation. Some make it all the way to the beach, picking their way gingerly over loose lava boulders.

ISLAND SPECIES WHERE THE SHELL SUITS

Over hundreds of thousands of years, variations in local conditions led to the emergence of several species of tortoise across the archipelago.

On arid islands, tortoises evolved flared ‘saddleback’ shells (below) and long necks allowing them to browse on tree-like cacti that provide a critical source of food

and water during prolonged droughts. On wetter islands, where grasses and herbs are abundant, species developed domed shells better suited to grazing.

These adaptations may even have changed the history of science. In 1835, the acting governor of the Galápagos boasted to Darwin that he could identify the island of origin of any tortoise by the shape of its shell – prompting a defining moment in Darwin’s development of the theory of natural selection.



Journeys begin abruptly, as if the tortoises simply wake up one morning and decide, there and then, to head off. During the months of the year when they are more sedentary, they travel on average about 30m each day. But this increases to around 250m in migration periods and, in a full-steam-ahead frenzy, a tortoise might manage as much as 1km.

But what motivates them to move? Imagine that you’re a 250kg reptile with short legs, battling over unstable lava boulders and through dense tangles of vegetation in full sun at the equator, gaining 400m of altitude on the uphill leg of the migration. It’s a gruelling slog – so why bother?

Life in a salad bowl

Two factors drive the Galápagos tortoise migration: seasonal shifts in the abundance and distribution of high-quality food, and reproduction. During the cool *garúa* season (“cool” being a relative term, since it is still pretty hot – usually over 20°C), the lowlands on Santa Cruz are desert-like, and food for the reptiles is scarce. So they head for the mist-shrouded highlands where plants grow well year-round. When the rainy season begins, the lowlands soon green up with highly nutritious vegetation, tempting the tortoises back downhill.

Why not stay in the highlands? Probably because the vegetation up there, though abundant, is fibrous, tough and hard to digest, unlike the lush new growth watered by the rains at lower levels. For a couple of months, tortoises that make the trek downhill are living in a



Alcedo Volcano on Isabela Island is home to the largest population of tortoises in the archipelago, containing several thousand individuals.

THE TORTOISE IS LIKELY TO HAVE A SECRET OR TWO THAT EVEN SILICON CHIPS AND FANCY STATISTICAL MODELLING WILL NEVER CRACK

veritable salad bowl.

The second point is that at the end of the rainy season, though lowland vegetation dies back, temperature and soil conditions here are just right for nesting. Once the eggs are laid, all of the adult males and some females return to the highlands, and the cycle begins again. But some females, and all of the immature tortoises, stay in the lowlands year-round, a strategy that must involve tricky calculations of the energy costs of staying behind compared with migrating.

During the first year of our research programme we tagged 32 more individuals from four species on three islands. These reptiles covered the full range of habitats occupied by Galápagos giant tortoises: a flat, arid and hot island (Espanola), one with highlands and heavy human influence (Santa Cruz), and a further mountainous area with almost no human activity (Alcedo Volcano on Isabela Island).

Espanola's tortoises don't usually migrate, probably because everywhere on that low, flat island is pretty much the same – so why go to the trouble of travelling? On Alcedo, as on Santa Cruz, there are big, predictable swings in rainfall and vegetation over large swaths of the island; the tortoises seem to anticipate these changes – precisely how, we don't know. Over time, our data will allow us to understand not only how the different tortoise species live and move in relation to climate and habitat, but also how the actions of humans may have

FACT FILE

GALÁPAGOS GIANT TORTOISE

SEVERAL *CHELONOIDIS* SPECIES

► **WEIGHT**
Up to 250kg.

► **LENGTH**
Shell: from 60cm in females of smaller species to 165cm in males of larger species.

► **ID TIPS**
Two main shell shapes: 'domed' covers most of body; 'saddlebacked' rises high over neck and head.

► **DIET**
Mostly grasses, herbs, cacti and the leaves of shrubs; fruit when available.

► LIFE-CYCLE

Female matures sexually at 20–25 years; digs nests in sandy soils and lays 1–4 clutches of up to 16 eggs per year. Lives over 150 years.

► HABITAT

Arid lowlands dominated by shrubs and cacti; wet highland areas of woodland and open pampas.

► STATUS

Vulnerable; some island populations very rare.



GALAPAGOS TORTOISE RANGE



affected these age-old routes.

Ancient survivors

Meanwhile, the old tortoises will carry on doing what they do. Any animal that can live for longer than 150 years, float at sea for months, colonise inhospitable rocky shores, survive years of drought followed by prolonged floods, and navigate through lava fields, past sulphurous fumaroles and up and down steep caldera slopes is likely to have a few survival tricks up its sleeve.

It is also likely to have a secret or two that even silicon chips, accelerometers and fancy statistical modelling on superfast computers will never crack.

At least, I hope so. 🍌

Stephen Blake is a field ecologist who works for Germany's Max Planck Institute for Ornithology.

HOW DO WE KNOW?

THE NATURE OF LIGHT

BY ANDREW ROBINSON

What is light? It's puzzled some of humanity's greatest thinkers for 2,000 years, especially since it appears to behave like waves as well as particles



Light is a somewhat confusing phenomenon, in that it can behave both as a wave and as a particle. This counterintuitive property of light kept some of our brightest minds (pun intended!) guessing for 2,000 years...

The Key Experiment

The interference of water waves on a pond's surface is a familiar phenomenon. Thomas Young showed that the same thing happens with beams of light

In 1802, in a lecture at London's Royal Institution, Thomas Young demonstrated a new device now known as a ripple tank. Its basic principle is that water is stirred up in a trough with a glass bottom illuminated from below, so that the water waves and their patterns cast shadows onto a white screen above the trough. When two sets of ripples are created, they interfere with each other, producing a pattern of agitated water known as constructive interference – where the wave peaks coincide. A pattern of smooth water is known as destructive interference – where a wave peak is cancelled by a wave trough.

If light were a wave, Young thought that it, too, might demonstrate constructive and destructive interference. A year or two after his lecture, working at home, Young split a beam of light using two narrow slits. As the two beams were diffracted by the slits, they interfered with each other and created a pattern of bright and dark stripes on a screen. Thus, light added to light could produce more light or, more surprisingly, darkness.

To Einstein, Young's experiment was “the next great theoretical advance” after Newton's work on optics, while physicist Richard Feynman said it was the “heart of quantum mechanics”.

Need to Know

Refraction

Light passing from one medium to another is bent by refraction – hence the ability of lenses to focus light rays, and the fact that a pencil placed in a half-glass of water looks bent. The refractive index of a medium is the ratio of the velocity of light in a vacuum to its velocity in the medium.

Diffraction

Diffraction is the bending of all waves by apertures and obstacles. The diffraction of light is not so obvious in ordinary life as its refraction, but it can be observed in the iridescent colours formed

by a CD or DVD under visible light. The surface of these discs is ruled with very close lines, which form a diffraction grating.

Photoelectric effect

High-frequency electromagnetic radiation such as X-rays can displace electrons from certain metals. However, this occurs only above a certain threshold frequency, never below it, regardless of the intensity of the radiation. The explanation for this requires the radiation to be quantised, with the energy of each quantum dependent on its frequency.

A young Isaac Newton conducting light experiments using a prism in the mid-17th Century. Newton favoured a corpuscular theory of light, and his great standing ensured that idea dominated scientific thought for many decades



CAST OF CHARACTERS

Five great minds who contributed to our understanding of how light behaves

1629-1695



▲ Christiaan Huygens

This mathematician, physicist and astronomer came from a rich and influential Dutch family. He is perhaps best known for his invention of the pendulum-regulated clock, but also improved the lenses of his telescope and discovered the rings of Saturn. His greatest achievement was his wave theory of light.

1642-1727

▼ Isaac Newton

This farmer's son became president of the Royal Society and needs no introduction as a mathematician and physicist. His laws of mechanics and theory of gravitation are his lasting monument, but his research into optics was also highly influential, despite his dogged adherence to the corpuscular theory of light.



1773-1829



▲ **Thomas Young** This child prodigy born in modest circumstances to English Quakers became probably the greatest polymath of his age. 'The last man who knew everything' was a London physician by profession, but his reputation was made in physics, the physiology of the eye and colour vision, and Egyptology.

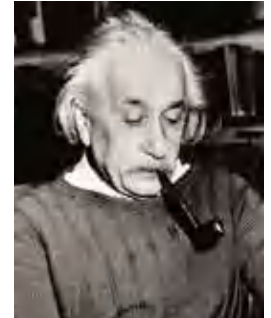
1831-1879

▼ James Clerk Maxwell

Maxwell was a Scottish physicist who founded the Cavendish Laboratory at Cambridge. He made key contributions to thermodynamics, the kinetic theory of gases and colour vision, but he's principally remembered for his field equations of electromagnetism, which defined light as an electromagnetic wave.



1879-1955



▲ Albert Einstein

Einstein is generally regarded as the greatest physicist since Newton, for his General Theory of Relativity and for his contributions to quantum theory. Born in Germany, he worked in Switzerland as a patent clerk, returned to his homeland as a professor and finally emigrated to the United States to avoid Nazi persecution of Jews.

TIMELINE

It took centuries to arrive at our current understanding of light – even today, the picture isn't entirely clear

11 C

Ibn al-Haytham shows that vision depends on light rays reflected from objects, not visual rays emitted by eyes. His work is translated into Latin in the 13th Century, influencing later European thinkers.



1690



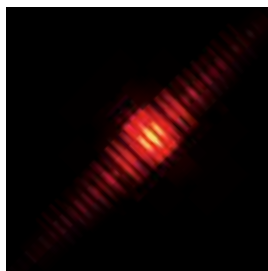
Christiaan Huygens publishes a wave theory of light. It explains refraction and diffraction, but depends on the existence of an 'ether', for which there is no evidence.

1704

After decades of experimentation, Isaac Newton publishes his *Opticks*. It explains some optical phenomena (but not others) with a particle theory of light, which does not require the existence of an ether.

C. 1804

Thomas Young establishes beyond doubt that light can behave as a wave by passing a light beam through two narrow slits and observing an interference pattern on a screen.



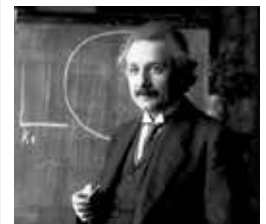
1865



Building on the work of Michael Faraday, James Clerk Maxwell predicts the existence of electromagnetic waves of varying frequency and wavelength, including light waves.

1963

Albert Einstein's Special Theory of Relativity postulates that light moves at a speed independent of the observer and does not require Maxwell's ether. Separately, he uses the photoelectric effect to postulate light quanta.



Andrew Robinson's books include biographies of Einstein and Thomas Young.

PUZZLE PIT



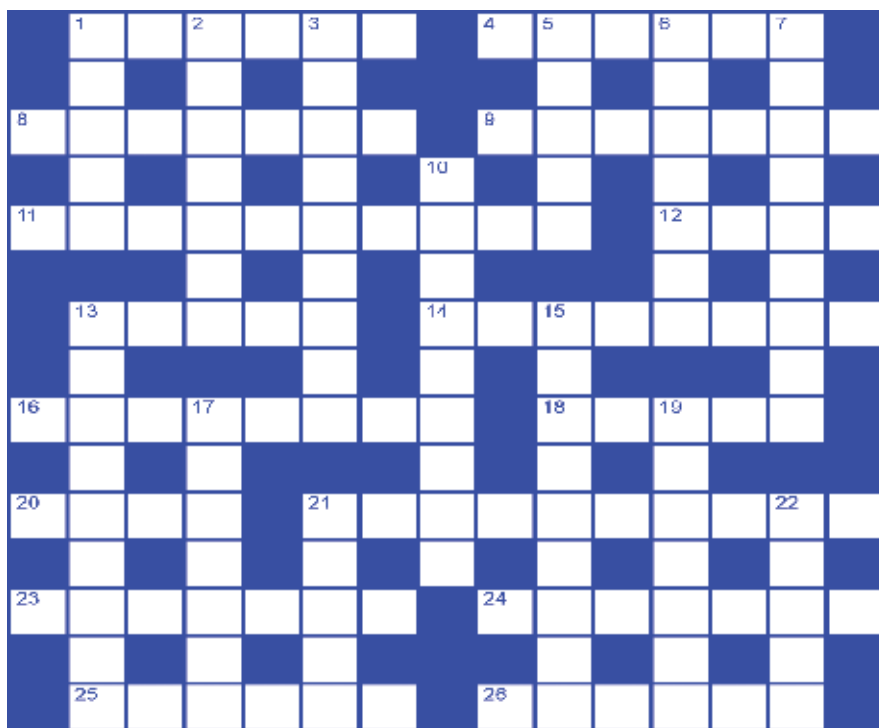
CROSSWORD NO. 28

ACROSS

- 1 Aspersions (6)
- 4 Former monetary unit of Portugal (6)
- 8 Outdoing or surpassing (7)
- 9 Contaminate (7)
- 11 Evaluation (10)
- 12 Stage hints (4)
- 13 Power of decision; mere assertion (3-2)
- 14 At all times; ordinary (8)
- 16 Agrees, approves or assents (8)
- 18 Force back (5)
- 20 Cook in an oven (4)
- 21 Frightened, harassed or intimidated (10)
- 23 To warn (7)
- 24 Character in "The Tempest" (7)
- 25 Moves suddenly and powerfully (6)
- 26 Edict (6)

DOWN

- 1 Foot-wear (5)
- 2 Lack of reverence; ungodliness (7)
- 3 Won ____ : won easily? (5,4)
- 5 Utter or say something loudly (5)
- 6 Ill-fated (7)
- 7 Immediately and promptly? (2,3,4)
- 10 Requisite (9)
- 13 Persons voyaging by hiding on board (9)
- 15 Become famous? (4,1,4)
- 17 Refuge or retreat? (7)
- 19 P in EPL (7)
- 21 Store of treasure (5)
- 22 Avoid (5)



YOUR DETAILS

NAME: _____

AGE: _____

ADDRESS: _____

PINCODE: _____

TEL: _____ MOBILE: _____

SCHOOL/INSTITUTION/OCCUPATION: _____

EMAIL: _____

How to enter for the crossword: Post your entries to BBC Knowledge Editorial, Crossword No.28 Worldwide Media, The Times of India Bldg, 4th floor, Dr Dadabhai Navroji Road, Mumbai 400001 or email bbcknowledge@www.co.in by **10 October 2015**. Entrants must supply their name, address and phone number.

How it's done: The puzzle will be familiar to crossword enthusiasts already, although the British style may be unusual as crossword grids vary in appearance from

country to country. Novices should note that the idea is to fill the white squares with letters to make words determined by the sometimes cryptic clues to the right. The numbers after each clue tell you how many letters are in the answer. All spellings are UK. **Good luck!**

Terms and conditions: Only residents of India are eligible to participate. Employees of Bennett Coleman & Co. Ltd. are not eligible to participate. The winners will be selected in a lucky draw. The decision of the judges will be final.

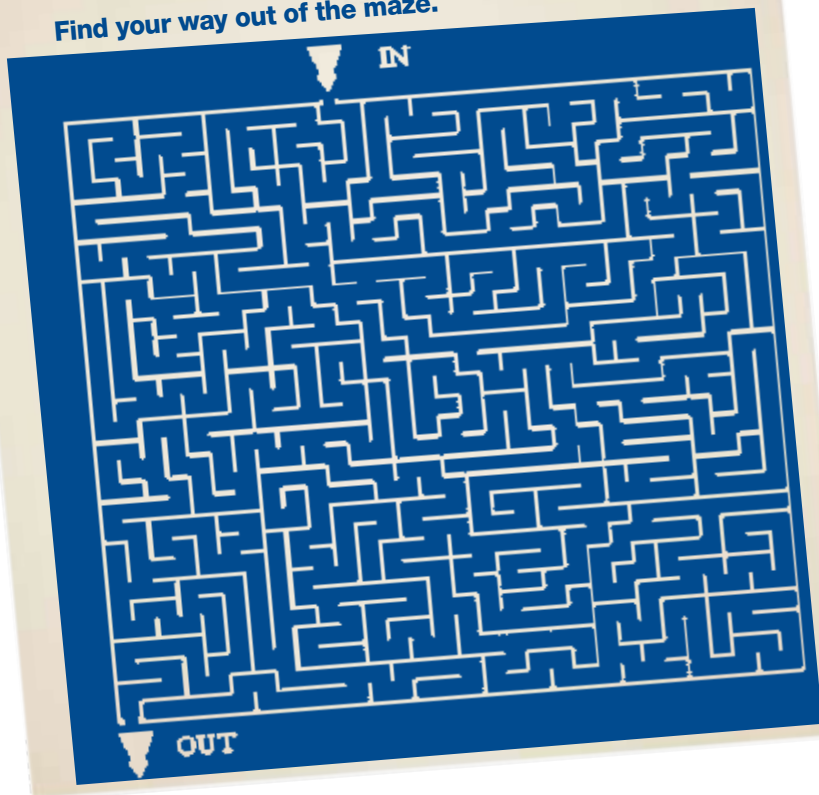
WINNERS FOR CROSSWORD NO. 27

Cashmere Lashkari, New Delhi
•
Manu Nicholas Jacob, Bengaluru

SOLUTION OF CROSSWORD NO. 27



Find your way out of the maze.



Q1 PICTURE SEARCH

In the jumble below, the words represented by each of the 16 pictures are hidden either horizontally, vertically or diagonally forward or backwards but always in a straight line. See how many of them you can find? Look out for descriptive names.



Q Q R E C O R D M F Q S G
R E T P O C I L E H S W O
U L V G K V I H J W U O V
N U R S E F F V U E E R O
T P I G R E B E C I E D M
E V D M X D G Y L W R P Q
V W B R E K C E P D O O W
N O S I L C Q H Y U O N B
B R A Z I L S E R Y D S P
A N U L A I K K K I S D Y
D E T D D N F E C A Q A J
G F L A O Z P E L T J H H
E E R M J I B G E A S E L

Q3 SCRAMBLE

Solve the four anagrams and move one letter to each square to form four ordinary words. Now arrange the letters marked with an asterisk (*) to form the answer to the riddle or to fill in the missing words as indicated.

SHIVE *
OSITH *
GHORCU *
EKNTUJ *

If we do not maintain ____, ____ will not maintain us. - Francis Bacon (7,7) (same word twice)

Q2 HEAD AND TAIL

Look at the clue to solve the answer in the form of a compound word. The second part of the next answer is the first part of the next answer.

Filthiest Very
Menacing glance
Check the dictionary?
The Arctic's locale
A body of water
Merchant vessel master
J. M. Barrie character Hook

MINDGAMES

Test your knowledge with our Big Quiz set by James Lloyd

- 1 Complete the headline: "Nose can detect one _____ odours"?
a) Million
b) Billion
c) Trillion
- 2 According to recent research, why might the giant bluestones of Stonehenge have been chosen?
a) For the sound they make when struck
b) For their ability to absorb the Sun's heat
c) For the way they cleave when struck, making them easy to shape
- 3 The Cassini spacecraft has confirmed the existence of a subsurface ocean on which of Saturn's moons?
a) Titan
b) Enceladus
c) Mimas
- 4 How have scientists nicknamed the *Anzu wyliei*, a recently discovered dinosaur species?
a) The lizard with no gizzard
b) The clawed cannibal
c) The chicken from Hell



The *Anzu wyliei* stood 3m (9.8ft) tall and had feathers

- 5 This Apollo 11 emblem, carried aboard the spaceflight that landed the first humans on the Moon, recently fetched how much at auction?

- a) \$12,500 (£7,464)
- b) \$62,500 (£37,322)
- c) \$112,500 (£67,180)



- 6 A McVitie's-commissioned study has found that which biscuit is best for dunking?
a) Rich tea
b) Ginger nut
c) Malted milk
- 7 According to Canadian researchers, what's one way that peacocks attract females' attention?
a) By offering their vomit as a present
b) By making fake sex sounds
c) By moving their necks in a figure-of-eight motion

- 8 Complete the recent headline: "Did _____ help kill off the dinosaurs?"
a) Dark matter
b) Tiny arms
c) Poisoned ferns

- 9 What's the name of the project that has detected the first gravitational waves from the Big Bang?
a) DRICEP2
b) TRICEP2
c) BICEP2

- 10 Which bird is the most regular visitor to British gardens, according to this year's Big Garden Birdwatch?
a) House sparrow
b) Blue tit
c) Starling

- 11 According to research published in March, the planet Mercury has shrunk by around how much over its 4.6-billion-year history?
a) 3km
b) 5km
c) 7km

- 12 A recent study by University College London researchers recommends eating how many portions of fruit and vegetables per day?
a) Five
b) Six
c) Seven

- 13 This adorable little critter was a recent arrival at Denver Zoo. What kind of animal is it?
a) Cheetah
b) Clouded leopard
c) Fishing cat



Ahh - what a cute _____

4 Mindgames: 1c, 2a, 3b, 4c, 5b, 6a, 7b, 8a, 9c, 10a, 11c, 12c, 13b
Q1 Picture Search: Brazil, badge, dice, easel, film, glass, helicopter, iceberg, jeep, ladle, monkey, nurse, radish, record, sword, woodpecker
Q2 Scramble: Words: Hives, hoist, grouch, junket
Answer: If we do not maintain justice, justice will not maintain us. - Francis Bacon
Q3 Head & Tail: Very-Dirty-Look-Up-North-Sea-Captain-Hook

SOLUTIONS:

EDU TALK

Dr Fr Francis Swamy, principal of St. Mary's (ICSE), Mumbai, speaks about how the 150-year old institution has remained at the forefront of academic excellence



The school has a history reaching back to 1864. How has learning at the school evolved with the passing of time?

Well, when you go back about 150 years, teaching and learning processes were limited to blackboard and chalk. Today, we have digital learning and teaching. In all our classrooms, smart boards (interactive boards) have been installed wherein the teacher has a store of information, and she has to know how exactly to tailor it for the 35-minute class. I have seen children using YouTube to download informative material for the learning process. This is a revolutionary change. It has gone from being a one-way discourse to being more interactive, more like a dialogue.

What values have stood the test of time?

The school has always laid stress on human excellence. We don't want to create academic robots. We want students to fully realise their potential. You may create an excellent businessman, but if

he doesn't have good values, what's the point of an education. You may create an excellent sportsman, but if he's going to get into match fixing etc., what values have I inculcated in my student? For us the ultimate benchmark are the values we have inculcated in our students.

According to you, what is the definition of a good education?

I would imply a process wherein a student becomes more aware of himself and his own potential, and then pursues that to the maximum, comparing himself with his own innate abilities. I don't believe in excellence where a student compares himself with the other students. That

for me is unhealthy competition. Always striving towards an extra 5% is what I feel education should draw out of students. The maximum they can do is their best.

What is the significance of global exposure today and what is your vision for students graduating from St Mary's?

Today, we must not limit ourselves to only Mumbai or India. Students must have a global vision. They must look big and think big. Certainly our loyalty and commitment is to our country first, but you should excel and compete at the global level. I think students must certainly think and live locally, but at the same time we must prepare ourselves globally.

I don't believe in excellence where a student compares himself with the other students. That for me is unhealthy competition

- Interview by Dushyant Shekhawat

TECH HUB

ON THE HORIZON

Super Slimline Screen

LG Display unveils a prototype 1mm-thick OLED screen

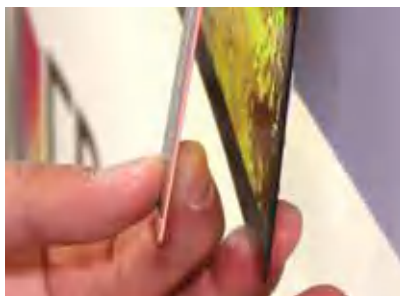
The ongoing battle among technology companies to produce ever-thinner screens ramped up a notch in mid-May, when LG Display – part of South Korea's giant LG Corporation – held a press event at its headquarters in Seoul to show off a TV screen that's less than 1mm thick. The screen in question is only a prototype, and sadly there are no plans for it to go into mass production any time soon. But it's a clear indication of LG Display's belief that OLED (organic light-emitting diode) technology represents the future when it comes to TV screens, computer monitors and smartphone displays.

Although it's only risen to prominence in the past decade, OLED has a long history, dating back to the 1950s when French researchers observed that some organic materials are electroluminescent – that is,

they give off light when subjected to an electric current. By making use of such materials, OLED screens obviate the need for the backlighting used in 'traditional' LCD/LED screens. This not only makes it easier to create slimmer displays, it also leads to improvements in energy efficiency, as well as offering a higher-contrast picture with deeper blacks. Motion response is also quicker than with LCD displays.

What's more, OLED displays can be printed onto a flexible plastic substrate, enabling the creation of screens such as this new prototype, which can be rolled up and carried around from one place to another – whether that's from the boardroom to a meeting room or simply from the living room to the bedroom. When you want to use it, the display is then wall-mounted using magnetic strips. ▶





We've come a long way from the cathode ray tube...

OLED displays can use several different architectures, but all essentially consist of anode and cathode layers, with an organic emissive layer and (usually) a conductive layer sandwiched between the two, all mounted on a substrate. AMOLED (active-matrix OLED) screens also include a thin-film transistor layer to switch each individual pixel on and off. The exact specification of the screen that was exhibited in Seoul hasn't been made public, but it's likely to have been constructed using a polyethylene terephthalate (PET) substrate. That's the same kind of polyester-derived plastic used to manufacture fizzy drinks bottles: in other words, such screens needn't be hugely expensive to produce.

Currently, OLED is mostly used in mobile phones, digital cameras, sat-nav units and other portable tech. That's

OLED screens can be mounted on a flexible plastic substrate, enabling them to be rolled up when not in use

because the high-contrast views offered by OLED work better in bright, sunlit conditions, while OLED's major drawback – the lifespan of screens can't currently compete with that of LCD or LED displays – is less of an issue when it comes to devices that are used only intermittently. Motorola, Nokia, Samsung, HTC and LG all manufacture and sell smartphones with OLED/AMOLED screens, and the technology can also be found in Diesel and Fossil watches, and in some televisions made by Samsung, Sony and, of course, LG.

LG, though, appears determined to lead the field. In January, the company signed a long-term deal with Universal Display Corporation, which holds most of the patents relating to OLED technology, and at the event in Seoul, Sang-Deog Yeo, head of LG Display's OLED Business Unit, said: "OLED is the first display technology sector that Korea will dominate from the beginning." LG is already working to build an 'OLED alliance' with Chinese and Japanese manufacturers, and says it hopes to sell 1.5 million OLED TV panels in 2016.

The display revolution, it seems, will be televised.

Russell Deeks is a freelance science and technology journalist.

TECHOMETER

WHAT'S HOT

WINDOWS 10

Microsoft's next operating system will be available as a free download from the end of July. Current Windows users will be able to upgrade for free for the first 12 months, and eagle-eyed users may have already spotted a new toolbar icon that lets you 'reserve' your copy now. Early reports suggest that this version remedies the flaws of the much maligned Windows 8.



WHAT'S NOT

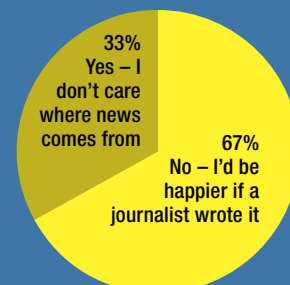
CASH

Cashless payment has overtaken use of notes and coins for the first time. The Payments Council has revealed that cash was used for just 48 per cent of purchases last year, and predicts a further 30 per cent drop in the next decade. The Council suggests contactless payments for small sums, and dwindling numbers of phone boxes and parking meters, have tipped the balance towards cashless payments.



READER POLL

Would you trust news that was generated by robots?



THE NEXT BIG THING

ROBOT REPORTERS

Earlier this year, Facebook announced that it would work with several news organisations – including *The New York Times*, *The Guardian*, and the BBC – to place stories directly into users' news feeds. Stories published using Facebook Instant will load more quickly and keep the style of the original publisher, who will keep all the ad revenue the stories generate – at least for now. The deal, currently only a pilot but likely to be extended, shows how vital social media has become to news organisations, and is a clear sign of how the world of news is changing – and has been for a while.

When Google News launched in 2002, many saw it as a harbinger of the death of the newspaper. It had no editor, just an algorithm that selected news stories from online publications and displayed them according to an index of interestingness known only to Google. More recently, the likes of Associated Press and Yahoo! have been experimenting with computer-generated prose. Both use software from Automated Insights to generate stories about company financial results and sports reports – areas where the quality of prose is felt to be of secondary importance to the accuracy of the data.

Facebook Instant feels like simply another step towards a world in which news stories are written by programmes, distributed by

Will Facebook Instant articles such as this one offer quality journalism?

algorithms and read on social media. The only thing likely to remain are the familiar brands, so we can choose to have *Guardian*- or *Sun*-flavoured stories sprinkled through our kitten-filled Facebook feeds like the odd healthy prune in a bowl of Sugar Puffs.

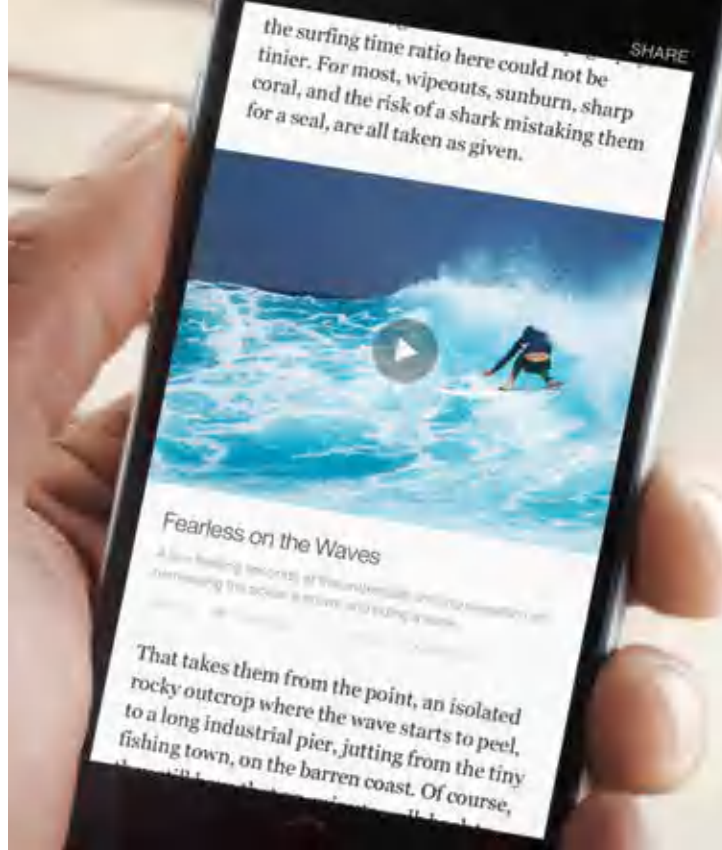
So what's wrong with that? If the job news organisations do is better served by Facebook Instant and its complex algorithms, why worry? Well, one concern is that Facebook, Google *et al* see journalism as a sideline, a way of putting people in front of ads. It isn't their primary mission – so if it stops making them lots of money, they're likely to stop doing it.

There's also a concern that what results is not actually journalism at all, because what

a human news team produces is actually quite fragile and special. A well-written news story puts information in context, offers a voice to each side of an argument and brings the public new knowledge.

Of course, I would say that. I'm a journalist, and I want you to believe in it because it keeps me in work. But simple economics and our seemingly unquenchable desire to live in the eternal present mean you'll probably choose an app-generated story over my carefully crafted prose – at least for your daily news. But I don't think the AIs will be writing *BBC Knowledge* features for a while yet.

Bill Thompson contributes to news.bbc.co.uk and the BBC World Service.



FROM THE LAB Wheels on the bus go round and round thanks to new charging system

WHAT IS IT?

A high-capacity charger for electric buses that has been developed at Germany's Fraunhofer Society, which also gave the world the MP3.

WHY IS THAT A GOOD THING?

Using electric vehicles for public transport is problematic. On average, buses travel 400km (250 miles) a day; to charge an electric one, you either need to fill half the bus with enormous batteries, or keep taking it off the road to charge.

The Fraunhofer chargers can be installed at a bus station, allowing the driver to charge up the vehicle while waiting for passengers to board.

HOW DOES IT WORK?

The driver manoeuvres the vehicle into position under a charging pole, which hooks up to a 'contact head' on the roof of the bus. It takes just 6.5 minutes to charge up specially developed high-capacity batteries. The system has been on test in Dresden since November 2014 and has been performing well.

Electric buses could help reduce smog in city centres



GAMES REVIEW

BATMAN: ARKHAM KNIGHT



Suit up as Batman and be the saviour of Gotham City in the resounding finale to Arkham trilogy, *Batman: Arkham Knight*.

PS4, Xbox One: ₹ 3499; PC: ₹ 1499

In 2009, Rocksteady Studios revolutionized the superhero game genre with *Batman: Arkham Asylum*. That game kicked off an epic trilogy that culminated in 2015's *Batman: Arkham Knight*, a game that took the franchise to an unprecedented scale.

The series' popularity can be attributed to its loyal adherence to comic lore, and the fact that players could live the experience of being Batman. In this game, the experience is even more immersive. Gotham City has been beautifully rendered, and there's more to explore than the previous two games. *Arkham Knight* also adds a crucial piece of the Batman experience to this game that was missing from the earlier two installments, the Batmobile. The iconic vehicle is uproariously enjoyable to use, allowing you to plough through city streets and waves of thugs alike.

Another departure from the earlier *Arkham* games is that there are no boss fights. Not having direct confrontations with the rogues

you're hunting feels strange at first, but you eventually learn how to work with Gotham City's police department. And you will be hunting a lot of villains. Plenty of characters from the comics make an appearance, from the infamous Joker, Two-Face and The Riddler, to more obscure foes like Man Bat, Penguin and the mysterious *Arkham Knight*. Batman's sidekicks aren't left far behind, with Robin, Catwoman and Commissioner Gordon playing a part in the story.

The gameplay remains similar to the first few games, an example of the developers not wanting to tinker too much with a good thing. The *Arkham* series introduced a novel system of combat that made role-playing combat much more dynamic, and that still feels intuitive even six years after its debut. All together, *Arkham Knight* cleverly blends brutal action with challenging puzzles and dramatic exposition, making it a fitting finale to what has been a stellar trilogy

FINGER ON THE BUTTON

ESPORTS COMES TO MUMBAI

This September, competitive gamers will collectively tremble in anticipation of the inaugural India Gaming Week in Mumbai. Sponsored by Lenovo, the tournament will feature 35 popular competitive titles, and run from 9 to 20 September. So start sharpening up those *CounterStrike*, *DOTA 2* and *League of Legends* skills ASAP!



TERMINATOR ENTERS THE RING!

When the next instalment of WWE's wrestling game, *WWE 2K16*, debuts in October, fans who've pre-ordered the game are in for a special treat. Arnold Schwarzenegger's iconic killer cyborg, the T-800 Terminator, is included as a playable character for those who pre-order the game. Surprised? Don't be. He always said, "I'll be back."



RESIDENT EVIL 2 TO BE REMADE

Seminal game publisher Capcom recently announced that it would be remaking its survival horror classic, *Resident Evil 2*. The franchise has even crossed over to the big screen, with a slew of loosely connected films, but this remake marks a return to the gritty and absolutely terrifying video game that started it all.



- Dushyant Shekhawat

GADGETS



Holga SLFT-IP5

Special Lens & Filter Turret
For iPhone 5

HOLGA PHOTO LENS

This is a phone cover with a difference. Just slide the Holga iPhone 5/5s Lens Filter and cover case on to your iPhone 5/5s and indulge in a bit of photography magic. Well, not literally. The phone case comes with nine different and quirky special effects without any app or software installed. Choose from the variety of effects offered by simply rotating the lens dial.

Price: ₹2,430 | www.amazon.in



BUDDY

Buddy is a robot who wants to be your friend. Seriously. Unlike C3PO, his face is more human friendly. An 8" touchscreen tablet serves with animatix eyes serve as his face, ensuring that interactions seem less stilted. He is ever ready to perform menial tasks for you, be it playing your favourite song on a loop, checking after the children or dogs, or even switching off the lights in the room. Buddy will be there for you, but not just yet. The designers at Blue Frog Robotics hope to release him into your house by November of this year. Till then, hold on to your human friends.

Price: TBA |

www.bluefrogrobotics.com

LEGO MINDSTORMS EV3 SERIES

Do you want build a robot? First, get your hands on the Lego Mindstorms EV3 series. Then select which robot you want to build from the five main robots there – R3PTAR (a cobra), the tank-like TRACK3R, the scorpionesque SPIK3R, your very own Terminator EV3RSTORM, and finally the muscle man –

GRIPP3R. Once that is done, you can programme these robots to follow your bidding thanks to the smart brick computer that controls the systems, modular sensors and Lego parts to create functional mechanical systems. Remember with great power comes great responsibility.

Price: ₹32,925 onwards
| www.amazon.in





DOCTOR WHO REMOTE CONTROL FLYING TARDIS

The Doctor couldn't make it, so he sent across the next best thing. His TARDIS! This 3" tall contraption is all yours to navigate, just make sure the handbrake isn't on! The IR controller allows for vertical take off and landing along with the usual left and right directional changes as you travel through time and space to find your next big adventure. Just remember, your TARDIS charges through USB from the handset that's battery operated.

Price: ₹3,3790 | www.amazon.in

DROPLET

This little drop is making huge waves! It keeps wet things wet and dry things dry. Ultra compact, waterproof and a 3 litre storage capacity, the Droplet by Matador is the tiny solution to your big first world problems. Designed as a keychain and packaged in the shape of a droplet, this wonder bag is probably a solution to a million things even the own inventors haven't thought of. You are welcome.

Price: ₹956 | matadorup.com



PRYNT

Prynt is a phone case that doubles up as an instant photo printer. Snap the case on your phone and then via the Prynt app, you can print any photos you want from your phone, Instagram or Facebook. More good news, it doesn't need Wi-Fi or Bluetooth, nor will it drain your phone's battery; it comes with its own battery. Available in four colours, the product is still in its manufacturing stages and will be available by early next year.

Price: TBA | www.pryntcases.com

RAZOR E100

Kids ride loud and proud with the Razor E100 electric scooter. Charge your scooter for about 40 minutes; give it a little manual push with your foot till you kick start the electric motor and you are off... tearing through the compound in your building, cruising at a speed of 40 mph. The handlebars are adjustable and come with front brakes..

Price: ₹41,296 | www.amazon.in



- Moshita Prajapati

INSIDE THE PAGES

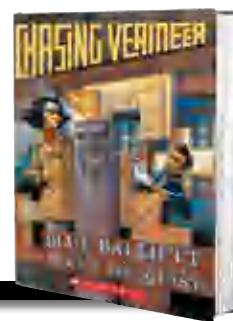
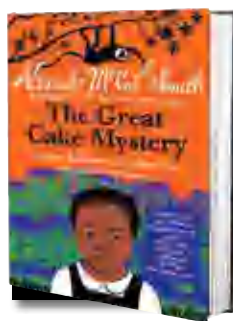
ON THE SHELF

YOUNG DETECTIVES IN FICTION

PRECIOUS RAMOTSWE –

A Very Precious Ramotswe Mystery For Young Readers by Alexander McCall Smith

Precious wants to be a detective when she grows up and as a precocious eight-year-old, she is practicing to be one. A prequel to the adult series, *The No. 1 Ladies' Detective Agency*, the series looks at the childhood days of Precious Ramotswe before she opened up her detective agency in Gaborone, Botswana. Smith has written three books in the young series so far, and as the novel progresses, we see Precious's burgeoning detective skills coming to fore, albeit with a little hiccup here and there, but she is still precious.



PETRA ANDALEE, CALDER PILLAY & TOMMY SEGOVIA –

Chasing Vermeer by Blue Balliet

Petra loves to read and write, Calder likes to solve puzzles and Tommy Segovia, considers himself as a treasure hunter. Together these 12-year-olds are the youngest detectives in the city of Chicago. The young detectives are powerful thinkers, with bright ideas and valuable insights into the mystery that leaves even the adults in their world stupefied.



THE BABY-SITTERS CLUB SERIES

By Ann Martin

While not detectives in the true sense of the word, the members of the Baby-Sitters club, Kristin, Mary-Anne, Stacy, Claudia, Dawn, Mallory and Jessie, do solve mysteries in the town of Stoneybrook; for instance what is the source of the mysterious noises that are emanating from the old Hennessey place or who is the phantom caller hounding the girls whilst they babysit. No one goes to jail when they mysteries are solved, but peace and happiness reigns.

THE FAMOUS FIVE

By Enid Blyton

Pop open the ginger beer and bring out a plate of ham sandwiches, because the Famous Five are here! As classic as they come, Julian, Dick, George, Anne and Timmy the dog are always up for adventure and never the ones to shy away from strange and mysterious happenings in the English and Wales moors and marshlands. Spread over 21 novels, the detectives were the bane of every criminal mastermind they came across thanks to the sleuthing methods, bravery and tenacity to get to the bottom of every mystifying occurrence.

NANCY DREW MYSTERY STORIES

By Carolyn Keene

Having a girl as a hero may not be as new now as it was in the 1930s when the girl detective Nancy Drew made her first book appearance. And there has been no stopping her since; criminals have tried but they have failed miserably. Smart and independent, she takes on every challenge head-on with the intent to see the villain behind bars. She occasionally has help from friends Bess and George, and rarely from her boyfriend Ned. A reboot of the series in 2013, just goes to show how popular she still is, 85 years after her first appearance, and how readers are always up for an adventure with Nancy Drew, girl detective.

Our pick of the graphic novels that ought to be on your bookshelf

THE LIFE AFTER

BY JOSHUA HALE FIALKOV AND GABO

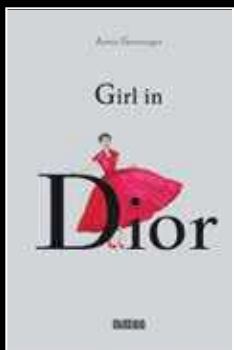


Sardonic in its tale, *The Life After* follows the awakening of Jude in the afterlife. That's right. Jude is dead. And is in Purgatory. And he has Ernest Hemingway for company, which is a bonus. Aware of his hopeless

situation and looking for a release, he starts looking for other souls who are stuck in Purgatory and starts a revolution so that the souls trapped here can escape to Heaven or Hell. But Jude is a glitch in the system, and must be terminated. The first in the on-going series, the adventure story is complimented brilliantly by Gabo's whimsical, romantic and quirky take on the after life.

GIRL IN DIOR

BY ANNIE GOETZINGER

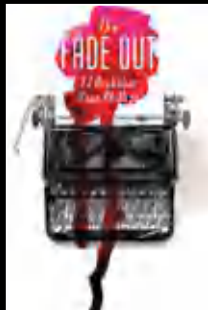


The book is described as an engaging and an inside look into the life of Christian Dior through a 10-year span (1947-57), where he created the New Look Silhouette that became the defining form

of feminine fashion. It is narrated through the eyes of the young journalist Clara, who ends up modeling Dior's new range when she is selected from the audience to replace a model. The illustrations are vivid without overpowering the text panel, which reads more like a conversation than a running text. It helps that the author and artist is a graduate in the history of fashion and arts. The book is perfect for an afternoon read with a cup of tea.

THE FADE OUT: ACT ONE

BY ED BRUBAKER



A throwback to the Hollywood Glam Era, this novel, inspired by the noir genre looks at the web of lies and deceit that had plagued the business of cinema. Set in the events of the year 1948, the novel chronicles and links multiple sub plots; a movie stuck in endless reshoots, a writer

damaged from the war and lost in the bottle, a dead movie star and the lookalike hired to replace her, with strong characterisations and visuals to reach an end that leaves the reader with hurried curiosity to know what happens next. Act Two will be out soon.

SECRET ORIGINS: VOLUME 1

BY DC COMICS

Late to the superhero universe that plagues every movie screen around you? Fear not. The marketing Gods at DC Comics have decided to bless us with a combined volume that traces the origins of some one of the greatest superheroes of our time. Batman, Superman, Green Lantern, Bat-Girl, Robin, Green Arrow,... you get the drift. The narrative story panel stays true to the original story lines, but is punctuated with illustrations that draw in the emotional turmoil of the characters. An entertaining afternoon for readers to who are new to universe and for the fans, more information is always welcome to better understand their superhero.



DID HE SAY THAT!?

"One of the drawbacks to life is that it contains moments when one is compelled to tell the truth"

- P. G. Wodehouse

QUESTION OF THE MONTH

A book I couldn't finish reading and why?



I enjoy reading, and even though I normally finish a book I pick up, one book that I couldn't finish to the end was *A Game of Thrones*, by George R. R. Martin. I read the book at the same time as the popular TV show based on it was launched. The show is an accurate representation of the events in the book, but the twist at the end shocked me. After seeing it once on TV, the death of a beloved character was something I could not relive in the pages of the book, so I never finished the novel.

- Kiran Advani, Delhi

READER REVIEW

Let It Snow

By John Green, Maureen Johnson, Lauren Miracle

Wow, this was a superb novel by the three authors. This is one of the finest works that I have read. It is full of romance, snow and more romance and more snow.

It's a must-read novel and a decent start for all the new readers. I thoroughly enjoyed it. So just give it a read and you will fall in love by the mesmerising beauty of this novel.

- Divya Naik, Xeldem Quepem, Goa.

- Compiled by Moshita Prajapati

IN FOCUS



“The question is not whether we are able to change, but whether we are changing fast enough”

- Angela Merkel, Chancellor, Germany

LEGACY

In 2005, Angela Merkel a German politician, achieved two remarkable firsts. One by becoming Germany's first woman Chancellor, and second to be the first Chancellor to come from the erstwhile communist nation of East Germany, or the German Democratic Republic (GDR). Today, Merkel is widely considered to be one the most powerful people in the world, entering her 10th year as German head of state while also serving as the de facto leader of the European Union (EU).

Merkel grew up in East Germany and began to get actively involved in politics once the Berlin Wall fell in 1989. The series of political mergers in the aftermath of Germany's reunification saw Merkel end up affiliated

with the conservative Christian Democratic Union (CDU), where she became the protégé of the then-Chancellor, Helmut Kohl, and was appointed to the Cabinet under him.

Merkel rose to lead the CDU and in 2005, the party's election victory facilitated her first term as Chancellor. Nuclear disarmament and cultivation of sustainable energy sources have been some her government's noteworthy achievements.

Due to her position at the head of one of Europe's strongest economies, Merkel was instrumental in combating Europe's recession in the early 2000s. Her influence over world affairs continues to grow, even in the 10th year of her chancellorship.

DID YOU KNOW

- Merkel has a documented fear of dogs.
- Merkel is a great fan of football, even travelling to the national team's games in her capacity as Chancellor.
- Due to her East German upbringing, Merkel is a fluent speaker of Russian.
- The German populace jokingly refers to Merkel as Mutti, German for mother.
- From 1978 to 1990, worked as a researcher and was awarded a doctorate for her thesis on quantum chemistry.



Merkel interacts with Brazilian President, Dilma Rousseff



Merkel addresses representatives of the European People's Party in 2014

- Dushyant Shekhawat



Knowledge



Knowledge

INCORPORATING



**SCIENCE
WORLD**

SCIENCE • HISTORY • NATURE • FOR THE CURIOUS MIND